The Metric Guid

Council of Ministers
of Education, Canada

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The Metric Guide

Distributed by the Ontario Institute for Studies in Education for the Council of Ministers of Education, Canada.

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This is the symbol of the Council of Ministers of Education, Canada. It symbolizes the interprovincial nature of the organization, the ten provinces which constitute its membership and the five-region concept which provides the operational structure for many of the Council's task forces and work groups.

The National Symbol for Metric Conversion, a stylized M and maple leaf, symbolizes metric conversion in Canada.

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Foreword

In September of 1973, the Council of Ministers of Education approved a recommendation submitted by its Curriculum Committee that a metric task force be established to carry out a preliminary investigation relative to metric conversion in the area of elementary and secondary education. Operative since March 1974, the task force focused its efforts on the development of a metric style guide which would be of use to educators as well as anyone interacting with the education sector. A draft of this document was submitted to the Council in September 1974 and received the ministers' approval for publication and distribution to all teachers in elementary and secondary schools across Canada.

It is hoped that this guide will enable users to understand and apply SI (Système International d'Unités) to everyday life with ease and confidence. In fact, this document has been written with the intent of being helpful to the greatest number of individuals in the education sector, as well as to the general public.

On behalf of my colleagues on the Council, I would like to extend our sincere appreciation to the Metric Task Force members, John Ardenne of Halifax, Jack Bell of Toronto, Willard Dunlop of Victoria, Jean-Guy Gagnon of Quebec City, and Gerald Hawley and Morris Treasure of Edmonton, for their dedicated work and impressive achievement in such a short period of time. Mr. Bell, as chairman of the group, deserves our warmest thanks for the fine leadership he provided in this undertaking.

We gratefully acknowledge the cooperation and assistance given by the Metric Commission at every stage of the project. Particular mention must be made of the Commission's financial support with respect to the travel of task force members as well as the preparation of the French version and the screening of the document. Valuable help was also received from representatives of the Canadian Teachers' Federation, the Canadian School Trustees' Association, l'Association canadienne d'éducation de langue française, the Canadian Home and School and Parent-Teacher Federation and both the English and French language publishers. In addition, our thanks go out to the many people who assisted in the arduous process of revision and validation.

Lastly, we extend our thanks to the members of the Council secretariat who provided the necessary organizational and secretarial support to the task force for this project.

Thomas L. Wells

Thomas L. Wells
Chairman
Council of Ministers of Education,
Canada

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Its authorization

This *Metric Guide* has been prepared by the Metric Task Force of the Council of Ministers of Education, Canada. The original edition, titled *Metric Style Guide*, was made available to all schools in Canada. The name *The Metric Guide* has been given to this edition to indicate its potential for general reference use. This is an official document of the Council and has received the approval of the Metric Commission in Ottawa regarding conformity with correct metric practice.

The guide is based on the recommendations set forth in Canada's official *Metric Practice Guide* CAN-3-001-02-73, a National Standard of Canada. The guide can therefore be accepted, at the discretion of each provincial Department of Education, as an authoritative document governing the correct metric style to be used in elementary and secondary schools to express metric measures.

While the Council of Ministers of Education hopes that this guide will provide a measure of uniformity across Canada with respect to metric terminology and symbolism, the Council also emphasizes that each province is responsible and free to implement the contents of this document in the curriculum of the schools in any manner deemed appropriate.

Its content

The Metric Guide deals with the correct style to be used in expressing metric terms, units of measure, and their symbols. It does not cover the teaching of the metric system. It is intended solely to give teachers information on the terminology and symbolism to be used as Canada adopts the modernized metric system known as SI.

The International System of Units, or simply SI (from the French name, Le Système International d'Unités), is the name given to the most recent version of the metric system. Canada is converting to SI; therefore, teachers should ensure that metric practice in their schools conforms to that of SI.

This guide presents several treatments of the metric system. These are covered in three parts.

Part A deals with common everyday units in Chapter 1, a few simple related features of common units in Chapter 2, and some fundamental rules of style in Chapter 3. Part A is intended for all teachers.

Part B outlines the structure of SI in Chapter 4 and gives a further extension of rules of style in Chapter 5. This part will provide a deeper understanding of the manner in which SI is put together. The majority of teachers are urged, at least, to scan this part. Chapter 5 includes fairly specialized features of SI that are not encountered too frequently in daily life. This is intended primarily for teachers of science, technology, and related disciplines.

Part C consists of Chapter 6 which includes tables of metric units, definitions, and other items of a reference nature. This is similar to the appendices found in many texts.

Finally there is a comprehensive index at the end of the guide.

Its use

The Metric Guide is not pedagogical, but informational, and should be used as a reference document rather than as a teaching guide. The order of topics is not necessarily that to be adopted in the curriculum.

In general, the guide is structured so that the simpler and more fundamental topics are dealt with at the beginning. The document becomes increasingly specialized towards the end. Because of this format, a single topic, such as that of length, is broken up into several parts throughout the guide. To mix the idea of a metre as "the width of a twin bed" with its definition in terms of "1 650 763.73 wavelengths of krypton radiation" seems inappropriate. In many sections there is an indication as to where the topic is continued further on in the guide.

Topics within the guide are numbered with three-digit numerals, such as 135. The first digit indicates the chapter, the second digit the section in the chapter, and the third digit the sub-section.

The Metric Guide is a reference document for teachers. It is hoped that it will be of assistance to them as they prepare programs of instruction for the first generation of "metric" graduates from Canadian schools.

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Part A

Chapter 1

Common metric units

Various metric systems

The two predominant systems of measure in the world today are the imperial and metric systems. We are in the process of converting from imperial to metric–but to which metric system?

The change to metric

111

Compare
1 league = 3 miles
1 mile = 8 furlongs
1 furlong = 10 chains
1 chain = 4 rods
1 rod = 5½ yards
1 yard = 3 feet
1 foot = 12 inches
with
1 kilometre = 10 hectometres
1 hectometre = 10 decametres
1 decametre = 10 metres
1 metre = 10 decimetres
1 decimetre = 10 centimetres
1 centimetre = 10 millimetres

Through the centuries, many measurement systems have developed, evolving from numerous origins, convenient customs, and local adaptations. Most systems have lacked rational structure. The imperial system–using the yard, quart, and pound –is one such conglomeration of poorly related units. See 601.

About 200 years ago, France decided to bring order out of her chaotic measures and the metric system was born. Although strongly opposed at first, this new system proved effective and gained popularity, so much so, that over 90% of the world's population now lives in countries that have adopted or are changing to the metric system.

Various versions of metric systems

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In Canada we measure energy in calories, kilowatt hours, ergs, joules, foot pounds, BTUs, electronvolts, horsepower hours, and therms.

There have been several metric systems, but each new version has added more metric units, causing unnecessary congestion. To make matters worse, in some applications there has been a mixture of both imperial and metric units, and something had to be done to clean house.

The latest version of the metric system

113

It's SI, not S.I.–omit the periods.

It's just called SI not the "SI system", since the "S" stands for the word "system".

In 1960 the International System of Units was established as a result of a long series of international discussions. This modernized metric system, called SI, from the French name, Le Système International d'Unités, is now, as a general world trend, to replace all former systems of measurement, including former versions of the metric system. Canada has decided to convert to SI.

Many European nations are making the change to SI–a change from former metric practice. The United Kingdom, Australia, New Zealand, South Africa, and others are adopting SI, while countries such as India, China, and Japan are updating their metric practice to conform to SI. The United States has recently passed a metric bill, and their choice, too, is SI.

SI is similar but different

114

Anders Celsius, a Swedish astronomer, proposed the scale, formerly called "centigrade", but now named "Celsius scale" in his honour.

In some parts of the world the "centigrade" is used to measure angles.
1 right angle = 100 grades
1 grade = 100 centigrades
A grade is often called a "gon".
These angular measures are proclaimed in French law.

The SI base unit of temperature is the kelvin, see 521, but for general use the degree Celsius is used.

SI includes familiar metric units such as the metre and kilogram. There are, however, a number of changes from former metric systems. For instance, the centigrade temperature scale is called the Celsius (pronounced *sell*-see-us) scale when used for general purposes. This is a change in name only, so that 20°C, formerly read as "twenty degrees centigrade," is now read as "twenty degrees Celsius." There is no change in the scale, only in the name. Water still freezes at 0°C and boils at 100°C (degrees Celsius, that is). This kind of change is not difficult for those who are familiar with older metric systems. Other changes are of a more specialized nature and are dealt with in Part B.

Common metrics with SI flavour

This first chapter is restricted to a simple treatment of everyday metric units that are likely to turn up at home, in shopping, or in travelling. A more formal treatment of the structure of SI is reserved for Chapter 4. However, when metric terms are mentioned, all units and symbols are used in conformity with SI practice. From a global perspective it is desirable to maintain an international language of measurement. *It is essential to note the international symbols carefully and to use them accordingly.* See 312, 340, and 615.

Example:
The symbol for metre or metres is simply m–with no period, printed in lower-case upright (roman) type–and remains unchanged in the plural.

The imperial system has no single outstanding characteristic. The metric system does–it focuses on the number 10.

121

Convenience created chaos

This may be stretching the point, but 1 league
= 3 miles
= 24 furlongs
= 240 chains
= 960 rods
= 2640 fathoms
= 5280 yards
= 15 840 feet
= 190 080 inches
= 570 240 barleycorns!
↑ Note the space
–no comma! See 343 c.

The imperial system was based on the convenience of things at hand. Centuries ago, the thumb inspired the inch; the foot left its imprint; the arm pointed to the cubit, yard, and fathom; and 1000 double paces led to our mile. This system has handy units but inconvenient conversion factors from one unit to another, like 12, 3, and 1760. When compounded to include more units of length, volume, and mass, the complexity becomes chaotic. The imperial system, with such conversion factors as 2, 3, 4, 5½, 6, 8, 9, 12, 14, 16, 22, 32, 40..., 1760, 4840, 5280, and 7000, is too cumbersome for perpetual use. See 601.

122

Numbers moulded metrics

1 cm = 10 mm
1 m = 100 cm
1 km = 1000 m

1326 mm = 132.6 cm
= 1.326 m

In Canada the spelling for the base unit of length is *metre*, as in other English speaking countries except the U.S.

The spelling, meter, is used for measuring devices such as the gas meter, water meter, thermometer, speedometer, barometer, and micrometer.

The metric system was based on the convenience of the decimal number system. Units are related by factors such as 10, 100, and 1000. This makes computation in the metric system much simpler than that with imperial measures. A great deal of the arithmetic merely involves the shifting of the decimal, without tedious calculations.

Admittedly, there are some inconveniences in the metric system due to its decimal structure. The jump from centimetre to metre is one that we are not used to, although the debatable decimetre might bridge the gap. The leap from gram to kilogram is large, and young students will be faced with numbers in the hundreds comparatively early in their encounter with metric measures.

The relative merits of the imperial and metric systems could be argued indefinitely. However, two centuries have demonstrated the unquestionable superiority and sweeping popularity of the decimal nature of the metric system.

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Metric prefixes

The nomenclature in this decimal structure is derived from a system of prefixes, which are attached to units of all sorts. For example, the prefix "kilo" means 1000, hence kilometre, kilogram, and kilowatt mean 1000 metres, 1000 grams, and 1000 watts, respectively. Most of our everyday experiences with metric units will involve some of the following prefixes. A complete list is given in 421.

Table 1 Some common prefixes

Name	Symbol	Meaning	Multiplier
mega	M	one million	1 000 000
kilo	k	one thousand	1 000
hecto	h	one hundred	100
deca	da	ten	10
deci	d	one tenth of a	0.1
centi	c	one hundredth of a	0.01
milli	m	one thousandth of a	0.001
micro	μ	one millionth of a	0.000 001

Using this notation for fun, we may say that a "decidollar" is a dime, a "centidollar" is a cent, and a "millidollar" is a mill, as used in tax rates. Some folk prefer the "kilobuck" or enter lotteries for the "megabuck".

Examples of the use of prefixes:

one megavolt = one million volts, that is, 1 MV = 1 000 000 V
one kilowatt = one thousand watts 1 kW = 1 000 W
one centimetre = one hundredth of a metre 1 cm = 0.01 m
one milligram = one thousandth of a gram 1 mg = 0.001 g
one microsecond = one millionth of a second 1 μs = 0.000 001 s

Note:

a) The most commonly used prefixes are kilo, centi, and milli.

b) Mega and micro are often used in science and technology.

c) Hecto, deca, and deci are well-accepted prefixes, but are used only in limited applications.

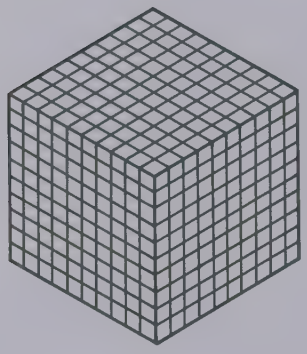
Pronunciations:
mega–*meg*aphone
kilo–*kil*owatt
(rhymes with willow)
hecto–*heck* toe
deca–*dec*adent
deci–*dec*imal
centi–*cen*tipede
milli–*mil*itary
micro–*mic*rophone

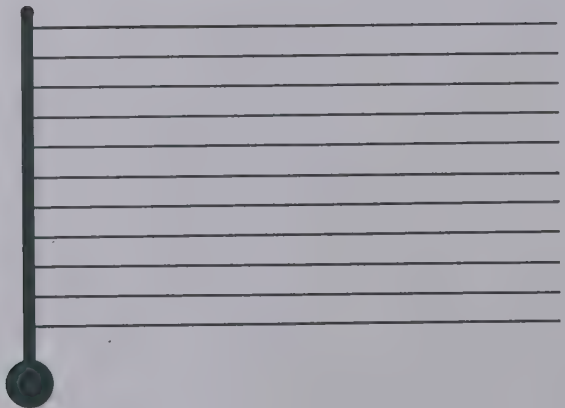
To ensure that prefixes retain their identity when pronounced, the first syllable of each prefix is accented. In particular, *kil*ometre should be pronounced with the accent on the first syllable, as is our custom with units such as kilolitre, kilogram, and kilowatt.

The accent on the second syllable generally applies to measuring devices, such as ther*mom*eter, spee*dom*eter, bar*om*eter, and mi*crom*eter.

Common everyday metric units

This Section, 130, deals with what may be called the most "familiar five" metric units. Sections 140 to 180 include more information on them and their multiples and sub-multiples. The chapter concludes, in Section 190, by putting them all together in a summary of common everyday units.





The "Familiar Five"

The symbols for units are printed in upright type, are not pluralized, and are not followed by a period (except at the end of a sentence).
The SI base units are the
metre (m)
kilogram (kg)
second (s)
ampere (A)
kelvin (K)
mole (mol)
candela (cd)
See 411.

"Familiar Five" is not official SI terminology; it's just a label given to the following units for the purpose of this document.

Table 2 The "familiar five"

Quantity	Unit	Symbol
Length	metre	m
Volume	litre	l (or ℓ)
Mass	gram	g
Time	second	s
Temperature	degree Celsius	°C

In Canada, the spelling is *litre*, as in other English-speaking countries, except the U.S.A., where *liter* is frequently used.

Both l and ℓ are recognized as international symbols for litre.

Note:

a) These should not be called the "basic units" of the metric system. This expression could be confused with "base units," which is an important expression in SI. There are 7 SI base units, as listed in the margin. Only 2 of the "familiar five" are also SI base units.

b) The international symbol for litre is the upright letter l. However, this may be confused with the number one (1). The cursive upright ℓ or the full word "litre" should be used to prevent confusion. If a prefix is used with litre, as in millilitre (ml) or kilolitre (kl), there is no need to use the cursive ℓ.

c) In the above table the word "quantity" means a measurable attribute, such as *length*; "unit" means a single arbitrary standard amount of the quantity, such as one *metre*; and "symbol" refers to the international representation of the unit, such as m for metre.

The metre (m)

Between 1791 and 1798, Mechain and Delambre surveyed an arc of the Earth's quadrant – from Barcelona through Paris to Dunkirk – under incredibly difficult and adventurous circumstances, to determine the length of a metre.

The base unit of length is the metre. Originally this was intended to be one ten-millionth of the distance from the equator to the North Pole. The metre was later defined as the distance between two lines engraved on a metal bar kept near Paris. Today, the metre is defined in terms of krypton radiation (see 606). For practical purposes in the classroom, the metre simply becomes the length of a metre stick.

Most doors in our homes are close to 2 m in height. Naturally, examples like these must be checked before a visual fixation is made.

Common objects or familiar markings can act as the most meaningful visual representations of the metre. The metre might be described roughly as half the height of a door, the width of a twin bed, the height of a three-drawer filing cabinet, the perimeter of this page, or the height of a man's hip, the height of a woman's waist, or the height of a young teen's bottom rib above floor level.

Estimate in metres the length and width of the room in which you are reading this book. Do not estimate in feet or yards and then convert. *Think Metric!* Measure to see how close your guess was.

Reference should not be made, any more than is necessary, to imperial equivalents of metric units. However, for those who have been steeped in the imperial system some comparison may be valid. For them, initially, the metre might be described as being a little longer than the yard. But this kind of description, on a continuing basis, should be avoided wherever possible. Such references should not be made with young students.

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The litre (l or ℓ)

The use of symbols is preferred to full names for metric units when used in conjunction with numbers. In general, this book will tend, first, to give the full name of a unit, and then show the symbol only. There is a list of common units in 312 and a more complete list in 615.

One tenth of a metre is called a decimetre–about the width of a man's fist. If a cube is made with each edge one decimetre long, the cube will have a volume of one cubic decimetre. This volume is also called a litre.

The symbols for these expressions are as follows:
dm for decimetre,
dm^3 for cubic decimetre, and
l or ℓ for litre. See footnote (b) of Table 2 in 131.

A litre is a little less than an imperial quart. A one-pound coffee can (the one pound has nothing to do with volume) happens to have a volume of about 1 litre. Eventually we may purchase milk in 1 ℓ, 2 ℓ, and 4 ℓ containers. Cherries and other small fruits may come in ½ ℓ, 1 ℓ, 2 ℓ, 4 ℓ, and 8 ℓ boxes and baskets. Perhaps 5 ℓ and 10 ℓ boxes will be used. The actual sizes will be determined largely by the packaging industry.

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The gram (g)

Estimate the number of litres of water in a pailful. Check to see how close you are to the correct answer. What is the mass of the water?

One group of students defined mass as the quantity of stuff, bits and pieces, particles and atoms and molecules, and any other "junk" in an object, no matter how loosely or tightly all the bits and pieces are packed.

A litre of water has a mass of almost exactly one kilogram. A kilogram mass is a measure of the quantity of matter or "stuff" in an object. Here, for instance, the kilogram of water may be turned into steam. The steam, under normal pressure, would have a volume of about 1700 ℓ, a much greater volume than when it was water, but its mass would still be one kilogram.

The original standard kilogram mass is represented by a solid metal cylinder kept at Sèvres, a suburb of Paris. The metal cylinder has almost exactly the same amount of "stuff" in it as does one litre of water. A kilogram mass is a little more than a mass of 2 pounds.

In SI, the base unit of mass is the kilogram, not the gram, but for this treatment "gram" is emphasized, as it is the term to which prefixes are attached. "Gram" is the common term, not the SI base unit of mass. The symbol for gram is g.

A steel ball-bearing about 3 mm in diameter, a medium-sized raisin, and a styrofoam ball about 4 cm in diameter each have masses of about 1 g. Their sizes or volumes are very different, but each has about the same quantity of "stuff", namely, 1 g.

A Smartie (coated candy) has a mass of about 1 g, a nickel has a mass of about 5 g, the receiver on a desk telephone has a mass of about 300 g, while the entire telephone has a mass of about 2000 g or 2 kg.

Packages of butter, cheese, meat slices, and so on, will probably be available in masses of 500 g, 250 g, and 125 g, or other modules as may be determined by the food industry. Thus the term "gram" will be a common household expression.

When he was in Florida, astronaut John Glenn lost *weight*. By this we mean that his *mass* decreased. The amount of matter in his entire body was less, probably through dieting and exercise.

When Neil Armstrong was on the moon his *weight* was much less than it was on Earth. This means that the *force of gravity* experienced by Armstrong decreased; it's much less on the moon, about one-sixth of that on the Earth.

There has been much controversy over the term "weight". "Weight" has sometimes been used to mean *mass*, and sometimes to mean *force of gravity*.

In this document the word "weight" is avoided because of its ambiguity. The term "mass" (not "weight") is used to refer to the quantity of matter in an object (rather than to the force of gravity acting on it).

In SI, mass is always measured in terms of the kilogram, gram, or some related unit–that is, a multiple or sub-multiple. Whenever a quantity is specified in such a unit, mass, not force, is the quantity under consideration. There is a further treatment of the mass-weight-force dilemma in the next chapter: see 240-244.

The second (s)

The second is the base unit of time; this is one measure that is unchanged as we switch to metric. The second is a recognized SI unit, but other common units of time, such as the minute, hour, and day, although non-metric, are permitted for use with SI because of their universal acceptance.

The millisecond (ms) is an example of an SI sub-multiple of the second.

Care should be taken to note the international symbols for units of time. They are s for second (not sec.), min for minute, h for hour (not hr.), and d for day. The symbol a for year is sometimes used; it comes from the word "annum". There seems to be no international symbol for week or month.

The degree Celsius (°C)

The unit of temperature for common use is the degree Celsius, with symbol, °C. See 114. In SI, the kelvin is the base unit of temperature. However, a temperature change of one kelvin is the same as a change of 1°C. Therefore, for common use the degree Celsius is substituted for the kelvin, which is used predominantly in science. For everyday measurements of temperature the degree Celsius is used and most teachers need not concern themselves with kelvins, which are discussed in 411 and 521.

Celsius" is always capitalized. The full name of the unit degree Celsius" begins with a lower-case letter in conformity with the rule stated in 341b.

Estimate the temperature outside in degrees Celsius.

Units of length

Is the perimeter of this page less than 1 m, more than 1 m, or very close to 1 m?

As Canada goes metric, the mile will give way to the kilometre; the yard and foot will step aside for the metre; and the inch, with its fractions, will be inched out by the centimetre and millimetre. Lengths, widths, breadths, heights, depths, thicknesses, distances, displacements, diagonals, diameters, circumferences, radii, perimeters, and so on are now coming under the rule of the metre.

Common length units

Someone has said: "Metric makes it 10 times easier, 100 times faster, 1000 times better."

In Canada, the preferred spelling is "deca", while in the U.S.A. and Australia it is "deka". The symbol is da in all countries.

The decimetre, square decimetre, and cubic decimetre are useful in teaching the structure of the metric system.

The symbol, μ, is a Greek letter, pronounced "mu", as a cat says "mew", not as a cow says "moo".

When μ is combined with a unit symbol, such as m, to form μm, the sub-multiple is read as "micrometre", not "mumetre".

The most common units of length are the kilometre (km), metre (m), centimetre (cm), and millimetre (mm). Relationships between these units are

1 km = 1000 m
1 m = 100 cm
1 cm = 10 mm

It is possible that the hectometre (hm), the decametre (dam), and the decimetre (dm) may be used for special applications, but it is probable that these will not become commonplace.

The decimal nature of the metric system is strikingly apparent in the following series of relationships.

1 km = 10 hm	1 km = 1000 m
1 hm = 10 dam	1 hm = 100 m
1 dam = 10 m	1 dam = 10 m
1 m = 10 dm	1 dm = 0.1 m
1 dm = 10 cm	1 cm = 0.01 m
1 cm = 10 mm	1 mm = 0.001 m

There are other metric units of length that are longer, such as the megametre (Mm), equal to one million metres; and some shorter units, such as the micrometre (μm), which is one one-millionth of a metre. These are not likely to be used in daily life, but a further list is given in 422, Table 16.

Range of lengths

The following chart gives an indication of a range of linear units from the megametre to the micrometre, with some examples to illustrate the various magnitudes.

It is suggested that students might develop a similar chart, using a suitable range and set of examples that are relevant to them. For young students, perhaps a chart showing only metres and centimetres would be a sufficient start.

Table 3 Range of lengths

		Halifax to Winnipeg	3800 km
1 000 000 m	$=10^6$ m $=1$ Mm megametre	Montreal to St. John (N.B.) Ottawa to Toronto	1000 km 400 km
100 000 m	$=10^5$ m	Vancouver to Victoria Toronto to Hamilton	100 km 65 km
10 000 m	$=10^4$ m	Niagara Falls to Power House Peace Tower to P.M.'s residence	10 km 3 km
1000 m	$=10^3$ m $=1$ km kilometre	Length of brisk 10 min walk Length of Olympic track	1 km 400 m
100 m	$=10^2$ m $=1$ hm hectometre	Olympic sprint: 100 m dash Height of Niagara Falls	100 m 50 m
10 m	$=10^1$ m $=1$ dam decametre	Height of 3-storey house Height of giraffe	10 m 5 m
1 m	$=10^0$ m $=1$ m metre	Half the height of bedroom door Length of tall man's forearm	1 m 50 cm
0.1 m	$=10^{-1}$ m $=1$ dm decimetre	Width of fist Length of egg	10 cm 6 cm
0.01 m	$=10^{-2}$ m $=1$ cm centimetre	Radius of nickel (5 cent piece) Diameter of pea	1 cm 5 mm
0.001 m	$=10^{-3}$ m $=1$ mm millimetre	Thickness of dime Thickness of credit card	1 mm 0.5 mm
0.000 1 m	$=10^{-4}$ m	Thickness of this sheet of paper Diameter of human hair	0.1 mm 70 μm
0.000 01 m	$=10^{-5}$ m	Diameter of red blood cell Thickness of spider web strand	10 μm 5 μm
0.000 001 m	$=10^{-6}$ m $=1$ μm micrometre	Size of bacteria Wave length of blue-green light	1 μm 0.5 μm

In what metric units will we measure the length of a pencil, width of a tennis court, depth of a tulip bulb, altitude of a cloud layer, distance from Earth to Mars, thickness of plastic sheeting, length of a couch, dimensions of a skyscraper?

As Canada switches to the metric system, various units of measure will be appropriate for different applications. It is certain that the distance between cities will be expressed in kilometres, but what about the dimensions of a bathroom wall tile; will it be commonly known as 100 mm by 100 mm, 10 cm by 10 cm, or 1 dm by 1 dm? At the time of writing it is not certain. We can be fairly sure of some applications and only make an enlightened guess at others. The following lists indicate possible uses of linear units. It will be of interest to note what actually occurs and make similar lists of the appropriate use of these and other metric units.

Guess how far, in kilometres, it is to a nearby town or city. How can you check how accurate your guess is *without* any use of the imperial system?

kilometre (km)

Highway distance signs, map scales.
Lengths of rivers, shorelines, lakes.
Distances between airports, capital cities.
Dimensions of the earth, moon, sun, planets, and their orbits.

Is there any man-made structure more than 500 m tall? If so, where?

Blue whales grow to a length of 35 m. True or false?

metre (m)

Dimensions of rooms, houses, lots, swimming pools, athletic courts.
Distances on golf courses.
Lengths of track and field events, horse racing events, fabric, rope, extension cords, hoses, garden beds, ladders, lumber.
Heights of buildings, trees, mountains, flight-paths.
Widths of hallways, carpeting, plastic sheeting, roads, rivers.
Depths of mines, canyons, lakes, oceans.

How high, in centimetres, are your eyes above floor level when you are standing? This may help you guess heights of other people.

centimetre (cm)

Body sizes: height, chest, waist, hips, neck.
Widths of wallpaper, fabric, foil, wax paper.
Lengths of belts, zippers, shoelaces, skis.
Dimensions of linens, furniture, appliances.

Estimate the thickness of some plywood and the width of some masking tape in millimetres. Do not convert! *Think Metric!*

millimetre (mm)

Widths of films, tapes, ribbons.
Lengths of nails, screws, bolts.
Dimensions of stamps, paper.
Diameters of lenses, drills, ball bearings, rope, buttons.
Thicknesses of plywood, metal plate, glass.
Dimensions on engineering drawings.

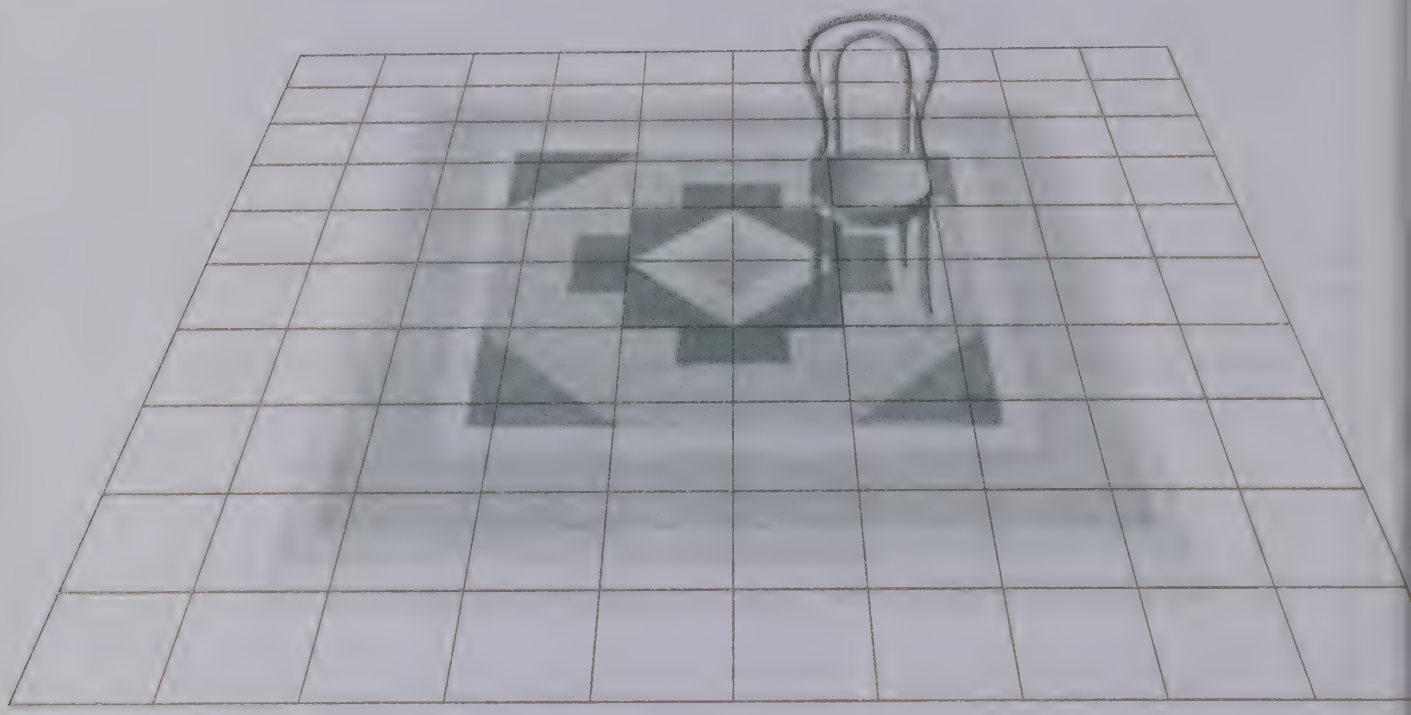
Units of area

If the room in which you are reading this book, is to be newly carpeted at $12.95/m², what will it cost?

The SI equivalent of the hectare is the square hectometre.

Square inches, square feet, square yards, and square miles are replaced by square centimetres, perhaps square decimetres, square metres, and square kilometres. Since area is two-dimensional, SI symbols for area units show the "two" as an exponent, as in cm^2 for square centimetre.

The acre is replaced by the hectare (rhymes with "air"). The symbol, ha, for hectare is not a part of SI, but is permitted for use with SI.



Units of area may be listed as follows:

square kilometre (km^2)

The population density of Canada is about 2.3 persons per square kilometre.

This is a comparatively large unit of area, generally used to measure the areas of surface regions on the earth.

square hectometre (hm^2)

What is the area of your school property in hectares? How can you determine this without converting from imperial units? Try it.

The square hectometre is called a "hectare", with ha as its symbol. We are familiar with the 100 m dash in track and field. The hectare can be visualized as the area of a square with sides 100 m in length. The hectare replaces the acre; in fact, a 100 acre farm is very nearly equivalent to a 40 ha farm. Now forget acres; think hectares!

square decametre (dam^2)

The "are" may be useful for those who solve crossword puzzles.

This unit will probably not be used. In some countries it is called the "are", from which the "hectare" gets its name. The "are" will not be used in Canada.

square metre (m^2)

Two full sheets of the Toronto Globe & Mail cover an area of 1 m^2.

This is the primary unit of area in SI. This unit will play an important role in many applications, one being the sale of carpeting by the square metre.

square decimetre (dm^2)

It is not certain, but possible, that construction materials, such as wall, floor, and ceiling tiles will be produced, using the decimetre as a module. If so, a wall tile *might* be a decimetre square and a floor tile *might* be a 3 dm or a 5 dm square.

Square tiles, 1 dm by 1 dm, may be useful for young students to work with in order to grasp the concept of area. Initially, the student need not know that the tiles have an area of 1 dm^2, but such tiles are of a convenient size, between the rather small square centimetre and the fairly large square metre. The everyday use of the square decimetre will not be very common.

cm^2

Each key top of a Touch-Tone telephone has an area of 1 cm^2. The round holes in the circular dial-type phone also have an area of 1 cm^2.

square centimetre (cm^2)

Graph paper and transparencies showing centimetre grids (without square millimetres) are available and can help students understand applications of the square centimetre.

mm^2

square millimetre (mm^2)

This unit of area is too small to warrant frequent use in everyday life.

Relationships between common area units are

$1\ km^2 = 100\ ha$

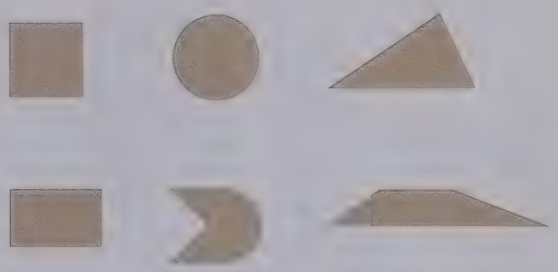
$1\ ha = 10\ 000\ m^2$

$1\ m^2 = 10\ 000\ cm^2$

$1\ ha = 1\ hm^2$
$= 1\ hm \times 1\ hm$
$= 100\ m \times 100\ m$
$= 10\ 000\ m^2$

$1\ m^2 = 1\ m \times 1\ m$
$= 100\ cm \times 100\ cm$
$= 10\ 000\ cm^2$

A unit of area need not necessarily be thought of as a square. An area of 1 cm^2 may have various shapes, for example:



How would you determine the area of
a) your thumb-nail,
b) the sole of your shoe?

In everyday life "square centimetre" is more easily understood than "centimetre squared".

If a unit of area contains the word "square" or "squared", the symbol shows the exponent ^{2}, as in cm^2, for square centimetre or centimetre squared. Abbreviations, such as sq.cm., are to be discouraged. See also 220-222.

If the calculation of an area is to show the units in the solution, it may appear as follows.

Area of rectangle = length × width
$= 5.0\ cm \times 3.2\ cm$
$= 16\ cm^2$

This step may be shown as $(5.0 \times 3.2)\ cm^2$.

Range of areas

The following is a sample range of areas that may be considered by some students.

Table 4 Range of areas

	Canada	9 976 140 km²
	Quebec	1 504 680 km²
1 000 000 km²	Newfoundland	404 520 km²
	New Brunswick	72 600 km²
	Lake Winnipeg	24 340 km²
10 000 km²	Prince Edward Island	5 600 km²
	Toronto	620 km²
	Ottawa	122 km²
100 km²	Fortress of Louisbourg Park (N.S.)	53 km²
1 km²	Thirty city blocks	1 km²
	Canadian Parliament Buildings	14 ha
1 hm²	Field inside an Olympic track	1 ha
	Baseball diamond	700 m²
	Tennis court	250 m²
1 dam²	Large classroom	100 m²
	Carpet (9 ft × 12 ft)	10 m²
1 m²	Card table (30 inch square)	0.6 m²
	Floor tile (12 inch)	9 dm²
	Long-playing record (12 inch)	7 dm²
1 dm²	Dollar bill	1 dm²
	Social insurance card	45 cm²
	Remembrance Day poppy	20 cm²
1 cm²	This square	1 cm²
	Hole in Lifesaver candy	35 mm²
1 mm²	This little square	1 mm²

Applications of area units

In Table 4, where would you place the area of Saskatchewan, Lake Superior, the nearest airport, your favourite park, a farm of your choice, the property where you live, a large store, a gymnasium, a desk top, a plate, a checker board, a quarter?

In farming, kg/ha and ℓ/ha will become familiar symbols.

The following are some examples of the possible use of units of area.

square kilometre (km²)

Areas of lakes, deserts, forests, oceans, counties, provinces, countries.

hectare (ha)

Areas of farms, parks, municipalities. Spreading of seeds and fertilizers in terms of kilograms per hectare, litres per hectare, and so on. Yields of crops may be given with reference to the hectare.

square metre (m²)

Areas of carpets, paint coverage, gardens, lawns, patios, driveways, cages in zoos, roofing, siding. Floor space in classrooms, offices, stores, elevators, tents, houses, apartments.

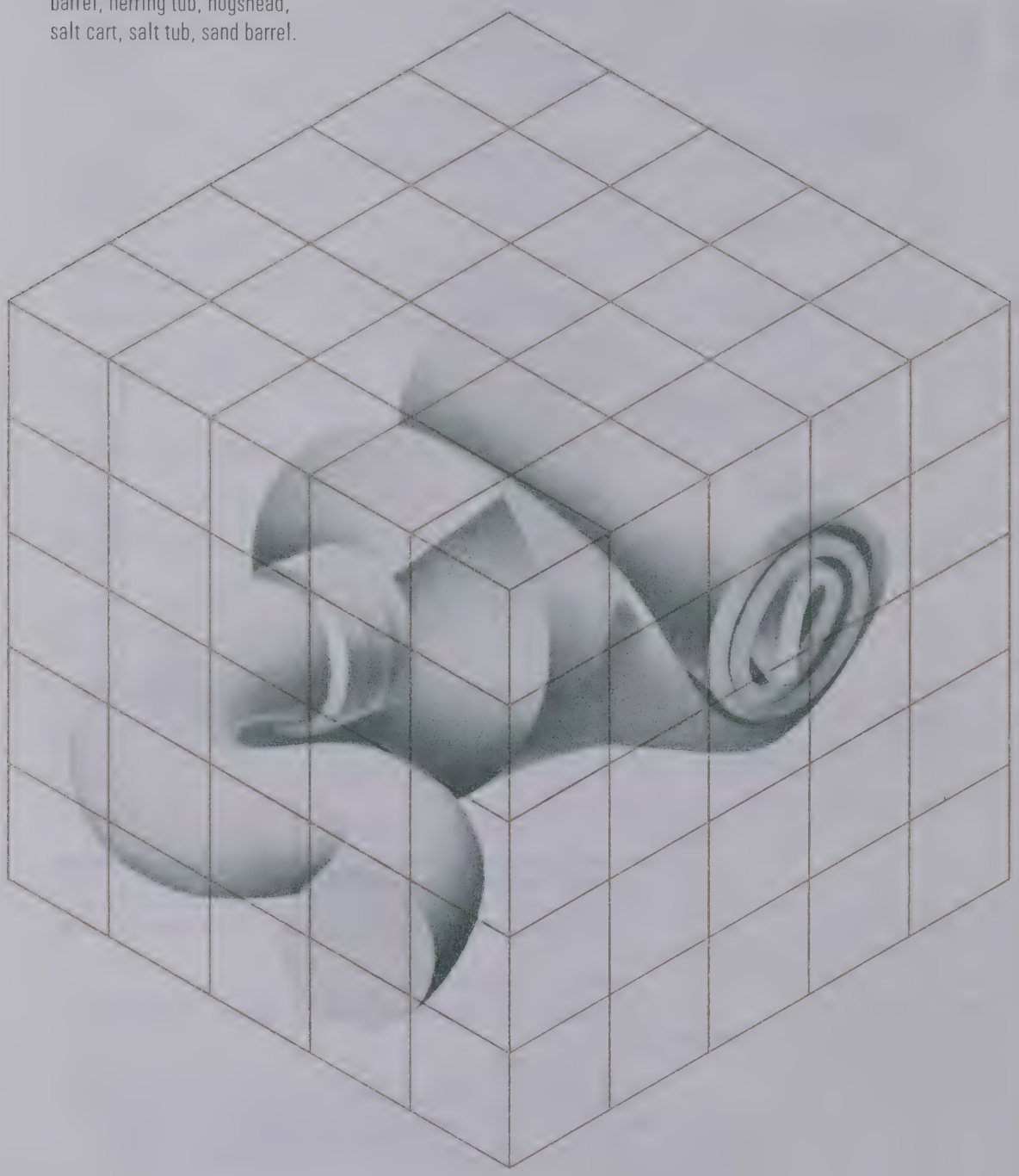
square centimetre (cm²)

Areas of cards, small tiles, newspaper advertisements, surfaces of small blocks and boxes, footprints, leaves.

Units of volume

The following imperial units of volume still appear in Canada: barrel, bushel, fluid dram, fluid drachm, fluid ounce, gallon, gill, minim, peck, pint, and quart. All of these are a different size in the U.S.A. In Newfoundland, the following volume units are still legal: herring barrel, herring tub, hogshead, salt cart, salt tub, sand barrel.

In the imperial system we have used two kinds of volume units: *cubic* units, such as the cubic inch, cubic foot, and cubic yard; and *capacity* units, such as the fluid ounce, pint, quart, and gallon. The former set will be replaced by the cubic centimetre, perhaps cubic decimetre, and cubic metre; the latter set, by the millilitre, litre, and possibly the kilolitre.



he abbreviation, cc, for cubic entimetre is not acceptable for se in SI. The symbol, cm^3, is to e used.

t one time, there was a very light difference between the ubic decimetre and the litre, or etween any two corresponding ubic and capacity units–only 8 parts in 1 000 000–not nough to concern most people. n 1964, this small difference vas removed and the litre is ow defined as exactly one ubic decimetre.

Common units of volume are the cubic metre (m^3), cubic decimetre (dm^3) and cubic centimetre (cm^3), often called cubic units and the kilolitre (kl), litre (ℓ) and millilitre (ml), often called capacity units. Cubic units are related as follows:

$1\ m^3 = 1000\ dm^3$

$1\ dm^3 = 1000\ cm^3$

Capacity units are related as follows:

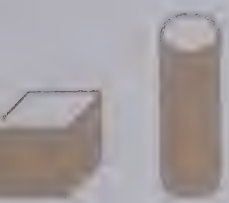
$1\ kl = 1000\ \ell$

$1\ \ell = 1000$ ml

Inter-relationships between these volume units are shown in the following chart.

Table 5 Volume units

Cubic units		Capacity units
$1\ m^3$	=	1 kl
$1\ dm^3$	=	$1\ \ell$
$1\ cm^3$	=	1 ml



1 dm^3 1 ℓ

t what stage can a young stu- ent realize that the above olumes are equal?

Cubic units are sometimes referred to as dry units of volume, and capacity units as fluid units of volume. Whether they are called cubic or capacity, dry or fluid, may not have much significance to young students. They must not be led into thinking that cubic and capacity units of volume are used to measure different attributes. All of these units can be used to express volume–the measure of three-dimensional space, whether occupied or empty, dry or fluid, regular or irregular.

Students are likely to meet the litre before coming across the cubic decimetre. A litre of milk and a decimetre cube of wood may appear to have nothing in common. This is a difficult concept; the idea that these have the same volume is not easily grasped.

Care must be taken to ensure that units of capacity are not unduly separated or compartmentalized from cubic units of volume. This does not mean that the litre and cubic decimetre should be taught simultaneously. But it is important that, when these units are experienced by students, they realize that the attribute or quantity being measured is volume. (See also 231 and 232.)

Besides the above-mentioned units of volume, it is possible that there may be applications of other units, such as the hectolitre (hl), decalitre (dal), decilitre (dl), and centilitre (cl), in particular sectors of Canadian life. At the time of writing it is impossible to predict the extent of such usage. The curriculum should not restrict students in their school program to the use of only the litre and millilitre, nor should it imply excessive treatment of all the multiples and submultiples of the litre, involving numerous problems with irrelevant units.

Until we have more information on Canada's program of metric conversion, extreme positions in designing the curriculum would be unwise. Some reference, without overdoing it, should be made to the hectolitre, decalitre, decilitre, and centilitre. This may be done merely to illustrate the completeness of the decimal structure of capacity units.

If a 10 ℓ pail becomes a popular household item, will we call it the 10 ℓ pail, the decalitre pail, the 1 dal pail, or just the pail? Will drinks be measured in centilitres? Will oil drums

Vith containers in these shapes, vater or sand may be poured rom one to the other to show heir equivalence in volume.

Kitchen measures or "recipe dispensers" may come in the ollowing range of volumes

1 ml
2 ml
5 ml
15 ml
25 ml
50 ml
125 ml
250 ml
500 ml
1 ℓ.

These are not necessarily called spoons or cups, just measuring devices to enable a person to dispense the correct volume of an ingredient in a recipe. The recipe might require 200 ml of milk, not 4/5 of a "cup".

A decalitre is a little more than the "peck", made famous by Peter Piper and his pickled peppers.

come in hectolitre sizes? What prefixes will be used? At the moment these decisions have not been made. Certainly there is little value in belabouring units such as the decalitre if there are no applications for them in real life. Teachers are advised to watch for such practical applications, if any, and judge accordingly.

Range of volumes

On the following chart, Table 6, where would you place the volume of an auditorium, your classroom, a freezer, a grain bin, a basket, a soft drink bottle, a blown-up balloon, a grapefruit, a tumbler, a box of chalk, a sugar cube?

The following chart indicates one range of volumes that may be relevant to some students. It is again emphasized that charts such as this one are given only as examples. Students could develop their own, using a span of volumes that is appropriate to them, with examples from their own experience or study.

Table 6 Range of volumes

100 m^3	**100 kl**	Boxcar	100 m^3
		Typical living room	50 m^3
10 m^3	**10 kl**	Washroom (6 ft×8 ft)	10 m^3
1 m^3	**1 kl**	Refrigerator packing crate	1 m^3
		Four-drawer filing cabinet	0.4 m^3
		Storage space in refrigerator	300 ℓ
		Oil drum (45 gallon)	200 ℓ
100 dm^3	**100 ℓ**	Large suitcase	60 dm^3
10 dm^3	**10 ℓ**	Large pail	10 ℓ
		Car engine displacement	5 ℓ
		Loaf of bread	3.5 dm^3
1 dm^3	**1 ℓ**	Brick (2 in×4 in×8 in)	1 dm^3
		Softball	480 cm^3
		*Kitchen measure	250 ml
		Tea cup	150 ml
100 cm^3	**100 ml**	Golf ball	40 cm^3
		*Kitchen measure	15 ml
		Walnut	12 cm^3
10 cm^3	**10 ml**	*Kitchen measure	5 ml
		Pair of dice	4 cm^3
1 cm^3	**1 ml**	Common marble	1 cm^3

*The kitchen measures shown above are close to the present cup, tablespoon, and teaspoon.

Look at a briefcase or small suitcase (cuboid in shape) and estimate its volume in metric units. Measure to find out how close you are. What unit of volume did you select?

Eventually, many people will consider the litre as the volume of a bottle or carton of milk that will keep them or the family going for a certain period of time. The litre will then be as significant as is our quart. When metric units come into general use, charts such as the one above should *not* make reference to imperial units. Here, some items are described by imperial dimensions, solely to identify the particular size.

Naturally, students should not be expected to memorize measures such as those given in Table 6. They should, however, be given ample opportunity to estimate volumes and other quantities, and then check their guesses by actual measurement.

Applications of volume units

The following are some examples of the possible use of various units of volume.

cubic metre (m^3)

Volume of a building or boxcar, capacity of the hold in a ship or the baggage compartment in a plane, storage space in a silo, amount of concrete in a dam, earth removed in an excavation, and volume of gravel, sand, or loam delivered by a truck. Water and gas consumption in our homes may be measured by the cubic metre.

ne cubic metre of water has a nass of one tonne (see next ection).

kilolitre (kl)

Liquid content in a swimming pool, reservoir, gasoline truck, or oil tank. The kilolitre may be used for water billing.

he cubic metre may serve equally well for these applications.

litre (l or ℓ)

Volumes of milk, drinks, solvents, paint, gasoline, anti-freeze, oil, bleaches, ice cream—in containers holding 1 ℓ or more. Capacities of cookware, jugs, kettles, pails, Thermos flasks, car radiators, gas tanks, refrigerators.

n many metric countries gas consumption of a car is measured in litres per 100 kilometres (ℓ/100 km). See 573.

cubic centimetre (cm^3)

Volumes of rectangular boxes, blocks, cones, cylinders, spheres, and other shapes whose volumes can be readily determined by mathematical formulae may be expressed in terms of the cubic centimetre (and perhaps the cubic decimetre).

A cubic centimetre or millilitre of water has a mass of one gram almost exactly).

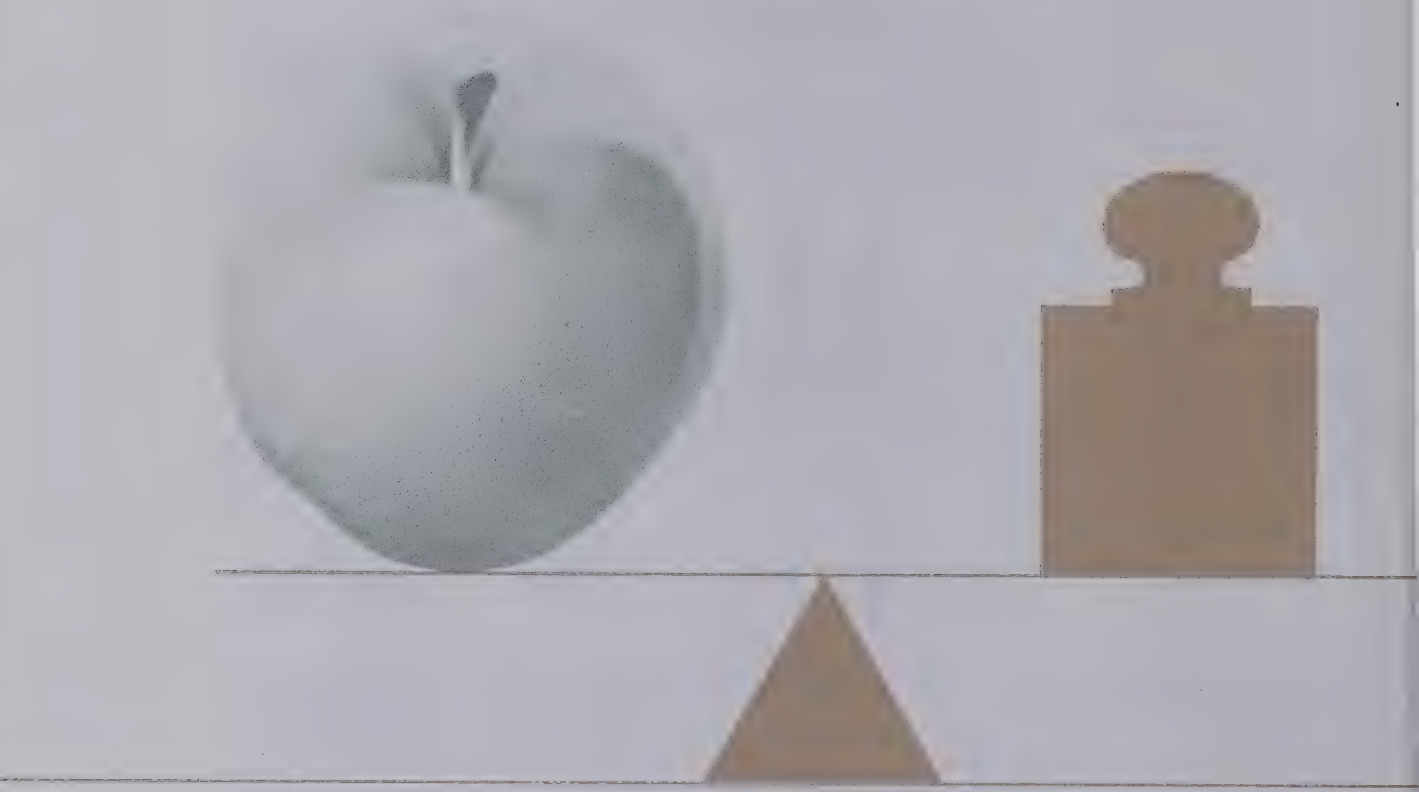
millilitre (ml)

Volumes of milk, soft drinks, shampoos, lotions, fluid medicines, toothpaste, solvents, paints—in containers holding less than 1 ℓ. Capacities of kitchen measuring devices.

In Canada, toothpaste comes only in sizes such as 25 ml, 50 ml, 100 ml, and 150 ml. Ounces have been squeezed out of the toothpaste business.

Units of mass

In the imperial system we have often referred to a mass of a ton, a pound, an ounce, and sometimes a grain. As we go metric we will refer to a mass of a tonne, a kilogram, a gram, and perhaps a milligram.



My mass is 80 kg and I am 180 cm tall, with a chest of 100 cm, a waist of 75 cm, and 100 cm hips. My sleeve length (shoulder seam to cuff) is 64 cm and my neck size is 40 cm. Am I a woman, man, girl, or boy? Can you be sure? What are your measurements?

In spoken English, if the context is not clearly metric, it is advisable to use the expression "metric ton" in place of "tonne"

Common units of mass are the tonne (t), kilogram (kg), gram (g), milligram (mg).

The relationships between these units are as follows.

1 t = 1000 kg
1 kg = 1000 g
1 g = 1000 mg

The SI term for tonne is megagram (Mg)–that is, 1 000 000 g–but common usage can be expected to popularize the word "tonne".

The spelling, "tonne", comes from the French and will distinguish the metric ton from the imperial ton in written English. Therefore, in writing, it is unnecessary to use the adjective "metric" to modify the word "tonne".

In French Canada, "tonne" means the imperial measure in certain contexts, so the metric ton must be shown as "tonne métrique".

The metric system is well co-ordinated. For all practical purposes, one litre of water has a mass of one kilogram. It is convenient, therefore, to know the following relationships.

1 m^3 or 1 kl of water has a mass of 1 t
1 dm^3 or 1 l of water has a mass of 1 kg
1 cm^3 or 1 ml of water has a mass of 1 g

Range of masses

On this chart where would you place the mass of a ship, a bus, a horse, a tiger, a concrete block, a dictionary, a pocket book, an apple, a paper clip, a rose petal?

Here is a limited range of masses that may inspire ideas for a similar chart that could be developed by a student.

Table 7 Range of masses

	Jumbo jet Boeing 747	340 t
100 t	Railway passenger coach	60 t
10 t	Elephant	7 t
1 t	Volkswagen	1 t
	Large motor-cycle	250 kg
100 kg	Heavyweight boxer	100 kg
	Slim young woman	50 kg
10 kg	Good sized Christmas turkey	10 kg
	Gallon of paint	7 kg
	Desk telephone	2 kg
1 kg	Pound of butter	450 g
100 g	Flashlight D cell	100 g
	Smallest tube of toothpaste*	40 g
	A slice of bread	25 g
10 g	A nickel	5 g
1 g	Medium raisin	1 g
	Small blueberry	500 mg
100 mg	Cherry stem	100 mg
	Postage stamp	20 mg
10 mg		
1 mg		

*Mass of tube and contents. The volume of toothpaste in this tube is 25 ml.

Butter is likely to be sold in 500 g packages. When this practice spreads across Canada the "*pound* of butter" entry in this table should melt away.

The use of units of mass may occur in examples such as the following.

tonne (t)

Mass of a truck, train engine, ship, airplane; load of bricks, steel, grain, cargo; annual yields of crops, amount of concrete poured, earth excavated, or ore mined.

kilogram (kg)

Mass of meat, vegetables, fruit, sugar, flour, packaged grains, fertilizer, cement.

International air flight baggage limits are 20 kg for economy and 30 kg for first class.

Of course you should know your own mass in kilograms.

Look at the labels on goods in the stores. How many incorrect symbols can you find? How many correct? The correct symbol for gram or grams is g in lower case and without a period.

gram (g)

Mass of many small goods: butter, cheese, meat slices, honey, syrup, molasses, peanut butter, powdered milk, mustard, yogurt, dips, whipped butter, loose candies, nuts, knitting yarn, putty and paste fillers.

There should also be a space between the numeral and the symbol as in 250 g, not 250g.

milligram (mg)

The milligram is a very small unit of mass.

Vitamins and minerals in cereals, for example, are often given in milligrams.

One Aspirin tablet contains 5 grains of pain-killer, which is a mass of over 300 mg.

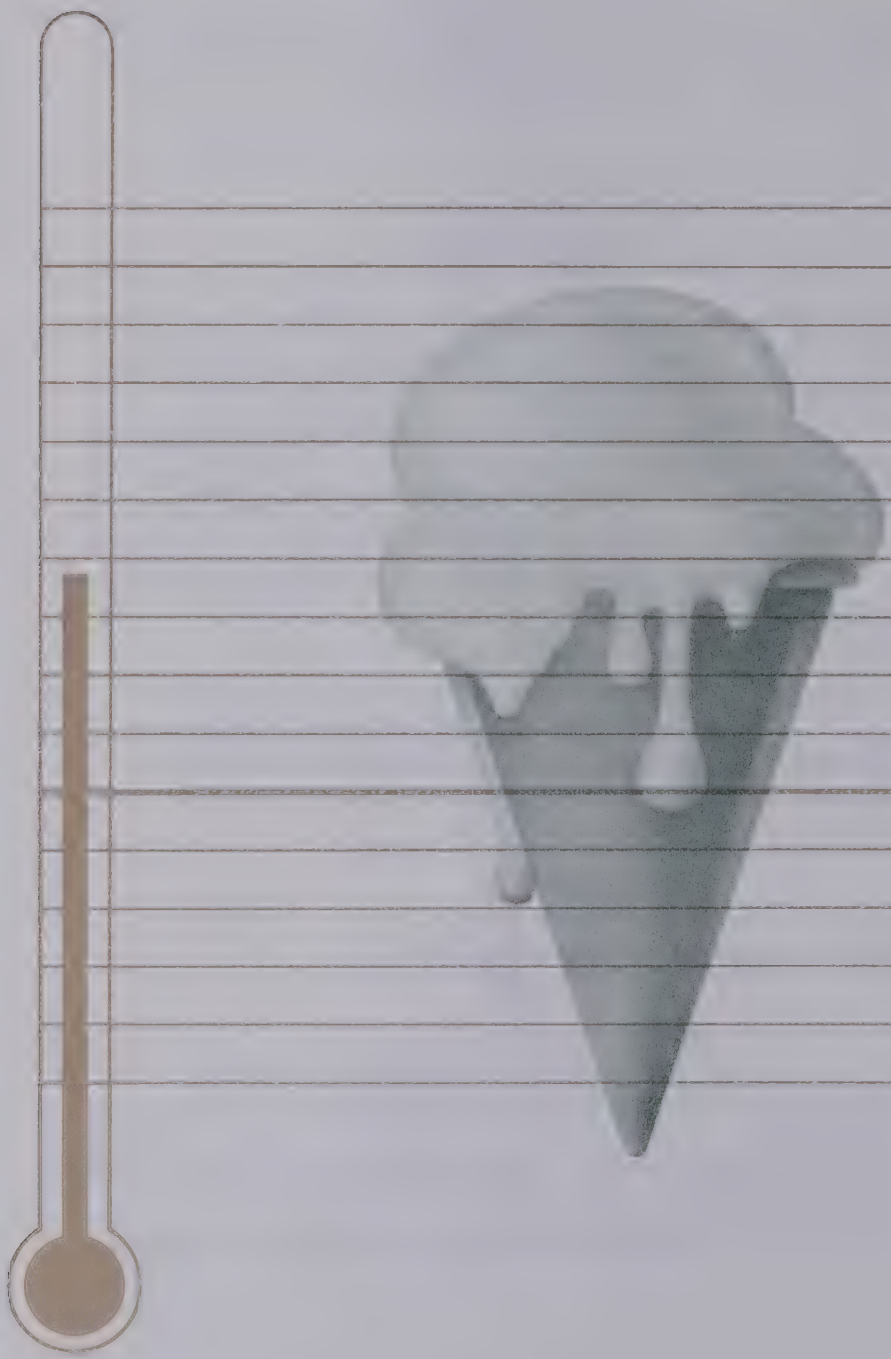
The labels on many drugs indicate the ingredients in milligrams.

One cereal shows the following–per 100 g of contents:

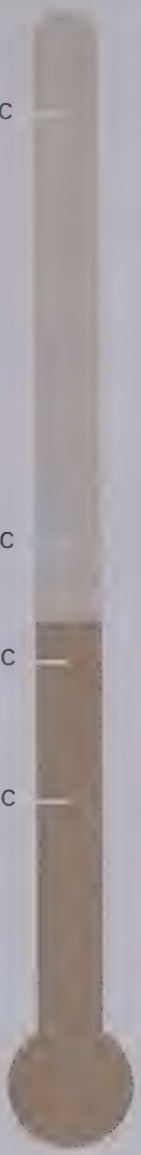
niacinamide	21.2 mg
riboflavin	3.5 mg
thiamine	2.1 mg
iron	14.1 mg

Units of temperature

As the Celsius temperature scale is introduced into Canadian life we must say, "Farewell! Fahrenheit," and "So long! Centigrade."



Common temperature units



The Celsius scale (formerly called the centigrade scale–see 114) was determined by setting the freezing point of water at 0°C and the boiling point at 100°C. The interval between these two fixed points was then divided into 100 equal intervals known as degrees Celsius. The scale extends below 0°C, using negative numbers, to the lowest temperature possible, −273.15°C (called Absolute Zero on the Kelvin scale), and above 100°C without known limit. (See 521.)

Two other common temperatures are "normal" body temperature, 37°C, and room temperature, 20°C, although many people prefer to keep their homes at about 22°C.

Sub-divisions of the degree Celsius are expressed as decimal fractions, for example, "His temperature is 38.6°C."

Range of temperatures

This chart shows a range of some temperatures.

Table 8 Range of temperatures

500°C		
	Wood alcohol burns	430°C
	Zinc melts	419°C
400°C	Mercury boils	357°C
	Lead melts	327°C
300°C		
	Wood burns	250°C
	Hot oven	210°C
200°C	Paper burns	185°C
	Medium oven	180°C
	Low oven	150°C
	Hottest on the moon	117°C
100°C	Water boils	100°C
	Alcohol boils	78°C
	Body temperature of song-birds	50°C
	Human body temperature	37°C
0°C	Water freezes	0°C
	Mercury freezes	−39°C
	Coldest weather (Antarctica, 1960 08 24)*	−88°C
−100°C	Alcohol freezes	−118°C
	Coldest on the moon	−163°C
−200°C	Oxygen freezes	−218°C
	Absolute zero	−273.15°C

What is the highest weather temperature ever recorded in Canada? What is the lowest?

Hottest weather temperature ever recorded in the world was 58°C (Libya, 1922 09 13)*.

*Numeric dating, see 251.

Clinical thermometers graduated in degrees Celsius are available in many stores.

Body temperatures

It is important to realize that an increase of 1°C is equal to an increase of almost 2°F; such an increase is serious when one is checking for a fever.

40°C is dangerous (equal to 104°F)
39°C is very feverish
38°C is feverish (consider calling a doctor)
37°C is considered normal

Air temperatures

The arbitrary chart shown in the margin may prove useful. See 604.

Oven temperatures

These will be recommended in metric cookbooks, but for those whose ranges have not been converted it is easy to remember: for oven temperatures only, the Celsius temperature is very close to half the Fahrenheit. A moderate oven, for example, of 350°F should be set at about 175°C.

Summary of common units

The following table shows a set of common units that will be used frequently in the everyday world.

Table 9 Common units

Quantity	Unit	Symbol	Relationship
Length	kilometre	km	1 km = 1000 m
	metre	m	1 m = 10 dm = 100 cm
	decimetre*	dm	1 dm = 10 cm
	centimetre	cm	1 cm = 10 mm
	millimetre	mm	
Area	square kilometre	km^2	1 km^2 = 100 ha
	hectare	ha	1 ha = 10 000 m^2
	square metre	m^2	1 m^2 = 100 dm^2 = 10 000 cm^2
	square decimetre*	dm^2	1 dm^2 = 100 cm^2
	square centimetre	cm^2	
Volume	cubic metre	m^3	1 m^3 = 1000 dm^3
	cubic decimetre*	dm^3	1 dm^3 = 1000 cm^3
	cubic centimetre	cm^3	
	kilolitre*	kl	1 kl = 1000 ℓ
	litre	ℓ	1 ℓ = 1000 ml
	millilitre	ml	
Mass	tonne	t	1 t = 1000 kg
	kilogram	kg	1 kg = 1000 g
	gram	g	1 g = 1000 mg
	milligram*	mg	
Time	day†	d	1 d = 24 h
	hour†	h	1 h = 60 min
	minute†	min	1 min = 60 s
	second	s	
Temperature	degree Celsius	°C	For water freezing point is 0°C boiling point is 100°C

*May not be common, but are useful for teaching
†These non-metric units are permitted for use with SI

Part A

Chapter 2

Further features of common units

This chapter deals with additional features related to the adoption of common metric units mentioned in the first chapter.

Is there a metric unit of length longer than the megametre or a unit shorter than the micrometre?

Large distances

211

The Great Spiral Nebula in Andromeda is about 2 000 000 light years away. This distance, in metric units, is about

19 000 000 000 000 000 000 km (kilometres), or
19 000 000 000 000 000 Mm (megametres), or
19 000 000 000 000 Gm (gigametres), or
19 000 000 000 Tm (terametres).

See Table 16 in 422.

Note: The symbols, Mm and Gm, stand for megametre and gigametre, not millimetre and gram. It is most important to use upper and lower case symbols correctly.

The prefix "giga" means a billion and "tera" means a million million.

Even the terametre, which is a million million metres, is very much too short a unit for expressing this great distance. In general, distances to stars are not given in SI units, but in non-metric units such as the light year, and the parsec (pc). See 511.

If just the solar system is being studied, comparison of lengths or distances can be made with the use of kilometres. For example, the Earth's diameter is about 13 000 km, and its distance from the sun is about 150 000 000 km; these two lengths can be compared readily. If the first length is expressed as 13 Mm and the second as 150 Gm, the comparison is not as easily grasped.

Small distances

212

The micron and angstrom have often been used to express small distances, but these metric units are not part of SI and are to be phased out. They will be replaced by the micrometre and nanometre, respectively. See 514.

The symbol for micron has been μ, but this is replaced by μm for micrometre.
1 micron = 1 micrometre
i.e. 1 μ = 1 μm
↑ obsolete ↑ SI sub-multiple

Area

220

An area may be shown as 24 m^2. Should this be read as "twenty-four metres squared" or "twenty-four square metres"?

Ambiguous terminology

221

The expression 4 cm^2, when spoken, may lead to confusion. Four square centimetres, four centimetres squared, four centimetre squares, and a four-centimetre square are all expressions that can turn up in the classroom. The teacher should take care to avoid misunderstanding.

An area of four square centimetres

Four centimetre squares

Recommended terminology

222

It is suggested that, to avoid confusion, 4 cm^2 be read as "four square centimetres" in preference to "four centimetres squared".

It should be pointed out that a "four-centimetre square" or, in symbol form, a "4 cm square" is one with sides 4 cm in length and has an area of 16 cm^2.

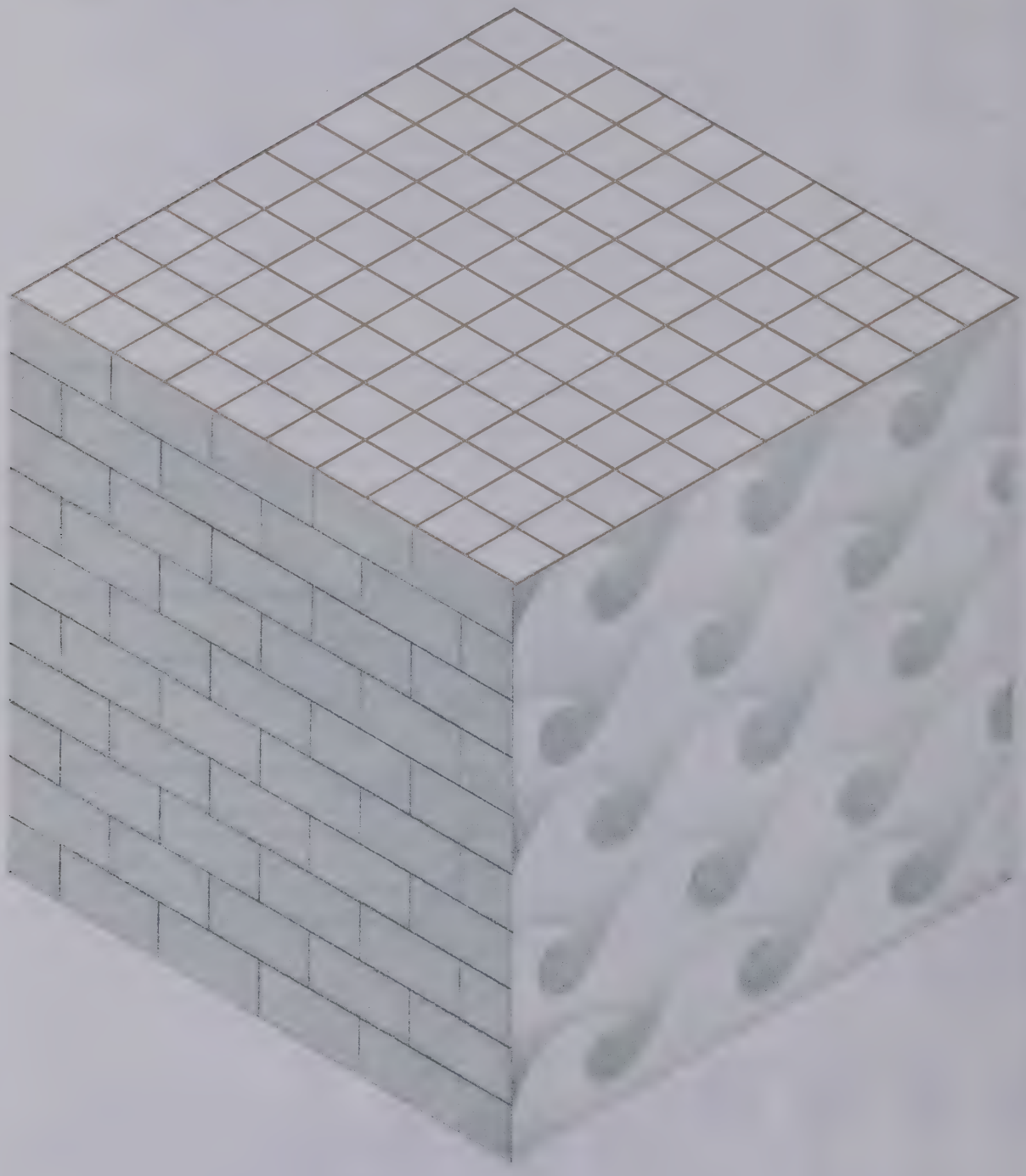
One illustration of "four centimetre squares" is shown above.

A four-centimetre square

Volume

The concept of volume includes that of capacity; these two, volume and capacity, must not be thought of as entirely different characteristics.

The volume of a cube that measures 10 cm by 10 cm by 10 cm
$=1000\ cm^3$ $=1000$ ml
$=\ 1\ dm^3$ $=\ 1$ l
$=0.001\ m^3$ $=0.001$ kl.



Capacity

231

If a fish tank were full of water, we might speak of the capacity of the tank and the volume of the water. Both would have the same measure, though they may be stated in different units.

Capacity refers to the internal volume of a container; it is a measure indicating how much the vessel holds. The capacity of a container is expressed in units of volume which are sometimes also called "capacity units". Through common usage the capacity of a small rectangular box is usually expressed in cubic centimetres, while that of a small bottle is stated in millilitres. This usage persists even though the cubic centimetre and the millilitre are exactly equal. It is not incorrect to refer to 32 cm^3 of water; the distinction between this and 32 ml is a matter of custom only.

Dry and fluid volumes

232

Truck loads of sand or gravel may be priced by the cubic metre.

The "capacity" of an auditorium could mean its volume, but would probably mean the number of seats. The auditorium takes up "space". Is this an area–meaning floor space–or is it the volume occupied by the entire building? One empty "space" during a concert pinpoints one empty seat–an area, volume, or point? Do students always know what we mean?

Cubic units of volume (cm^3, m^3, etc.) are often referred to as "dry units of volume". They are used to express volumes of solids, particularly those that may be calculated by formulae from linear measurements. Cubic units are also used for very precise liquid measures in science. In industry, volumes of gases are generally stated in cubic units.

So-called fluid units of volume (ml, ℓ, etc.) are often used to express volumes of liquids. In the classroom and grocery store, they may also be convenient for measuring approximate volumes of things that can be "poured", such as sand, rice, and blueberries.

The distinction between "dry" and "fluid" units of volume seems arbitrary; we just prefer not to talk about the volume of a brick in litres or the volume of milk in cubic decimetres, simply because we do not measure these items in these respective units. However, it must be remembered that the litre and cubic decimetre are identical units of volume.

Special applications

233

The "stere" (equal to a cubic metre and used sometimes to describe volumes of firewood) is not to be used in Canada.

Some decisions have not yet been made regarding certain practices pertaining to volume measures. In all probability there will be no need for the teaspoon, tablespoon, and cup. A recipe may require 2 ml of vanilla and 200 ml of milk and these volumes will be measured by means of an appropriate measuring device as mentioned in the margin in 161.

The bushel has no simple metric counterpart. Neither does the board foot, nor the cord. Large amounts of lumber may be sold by the cubic metre.

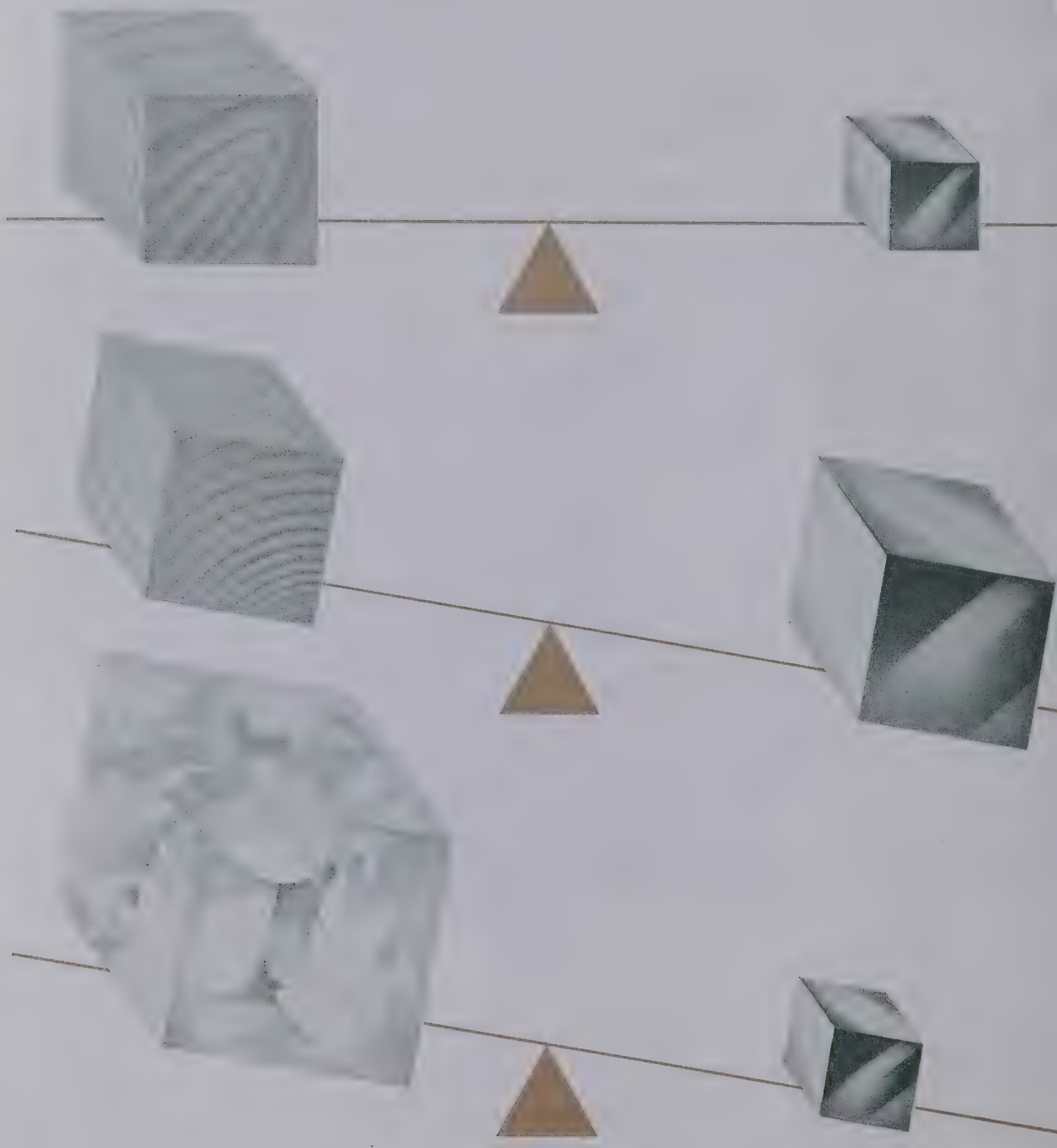
Cubic metres, in place of the hectare metre, can be used to indicate the volume of stored water.

The *hectare metre* is a unit of volume and may be used to state the amount of water in a reservoir–the surface area in hectares multiplied by the depth in metres. The symbol for hectare metre is ha·m and 1 ha·m = 10 000 m^3. See 342(l).

Mass

The mass of an object is a measure of the amount of material in the object. An object's volume may change quite drastically, as when water turns into steam or when a dry sponge is squeezed. But as long as particles of water or sponge do not escape the mass remains constant.

A force of gravity, pulling downwards, acts on each mass on the earth. Thus "mass" and "force of gravity", while entirely different characteristics, are linked. Section 134 emphasized that the word "weight" will be avoided in this document, since it is ambiguous; it sometimes means "mass" and sometimes "force of gravity", depending on the context.



Measuring mass

This spring scale is graduated in grams.

It is used to measure mass.

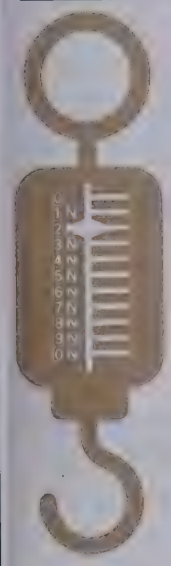
It could be called a "mass meter".

The mass of an object may be measured by balancing it on a teeter-totter against some calibrated standard masses. In the metric system, masses are given in grams and kilograms. Knowledge of the principle of this double-arm balance is needed in order to understand how mass is measured.

A spring scale may also be used for measuring mass. It is calibrated by hanging standard masses from it. But it should then be used under the identical conditions in which it was calibrated. It would have to remain at the same altitude for high-precision work. If, for instance, it were taken to the top of Mount Everest or transported to the moon, it would have to be re-calibrated, since the standard masses would produce different extensions of the spring. For low-accuracy work (within 0.5%) a spring balance, calibrated in grams or kilograms, can be used anywhere on the earth for measuring mass.

Through experiments students should learn that equal masses need not have the same volume; also that two objects which are identical in volume need not have the same mass. Further, it is important for students to realize that under some conditions an object's length, surface area, volume, temperature, and shape may change without any change in mass.

Measuring force



This spring scale is graduated in newtons.

It is used to measure force.

It could be called a "force meter".

Forces may also be measured quite simply by means of a spring scale, but the scale must be calibrated in newtons. The newton is the SI unit of force.

A student can pull on a newton spring scale and in this way "feel" a newton force. He or she can find out that it takes about 10 N (newtons) to lift a 1 kg stone, perhaps 4 N to pull it along the floor, and maybe 6.5 N to pull it up a ramp.

By lifting objects, a student may grasp the idea that there is a force of gravity pulling downwards on the object. When mature enough, the student may realize that all 1 kg masses on the earth experience a force of gravity of about 10 N. They can be informed that this force of gravity, acting on the 1 kg mass, would only be about 1.6 N on the moon and about 26 N on Jupiter. Gradually the concepts of mass and force of gravity can be distinguished by students at appropriate ages and levels of maturity.

In spite of the distinct difference between mass and force of gravity, the student will find that "weight" is often used as a synonym for either of these characteristics.

In the everyday world, "weight" generally means "mass"; as a rule, in scientific circles, it means "force of gravity". It is recommended that teachers introduce the term "mass" in relation to measures made in grams and kilograms. It is not wise to make a strong issue of this matter with students, particularly the young. The important issue is that students understand the meaning of mass.

24 cm^3 of pine wood has a mass of 19 g, and 24 cm^3 of aluminum has a mass of 65 g, hence there is more matter packed in aluminum than in the wood.

The terms "weight" and "weigh" may be used in the classroom when it is perfectly clear from the context which of the meanings is intended; most often in casual conversation the words will mean "mass" and "find the mass of". When recorded, however, these latter expressions should be used to avoid any ambiguity for the reader.

When forces are under discussion, it is clearer to say, "Find the force of gravity on the object," than to use the ambiguous request, "Weigh it."

243

Expressions involving "weight" or "weigh"

Many former expressions involving the words "weight" and "weigh" may require change if the concept of mass is to be clearly distinguished from that of force of gravity.

The following are suggested as possible examples for consideration. However, it is stressed that in all the examples, except (i) and (j), the so-called "old" expression is perfectly acceptable in everyday conversation, provided the audience understands that "mass" and not "force of gravity" is intended.

a) *Old* "What is the weight of the stone?"
New "What is the mass of the stone?"

b) *Old* "How much does he weigh?"
New "What is his mass?"

c) *Old* "Please weigh the pail."
New "Please find the mass of the pail."

d) *Old* "My weight dropped 11 lb."
New "My mass dropped by 5 kg." or "I lost 5 kg."

e) *Old* "Balance the stone with more weights."
New "Balance the stone with more masses."

f) *Old* "The dog's weight is 15 kg."
New "The dog's mass is 15 kg."

g) *Old* "That pillar supports a great weight."
New "That pillar supports a great mass."

h) *Old* "Her argument carries a lot of weight."
Old "That is a weighty matter."
Old "We must weigh the pros and cons."
Old "This paper-weight is an antique."
New No change!

i) *Old* "What is the weight of the astronaut on the moon?"
New "What is the moon's force of gravity on the astronaut?"

j) *Old* "In the space-ship the astronaut became weightless."
New "In the space-ship the astronaut experienced no apparent pull of gravity."

244

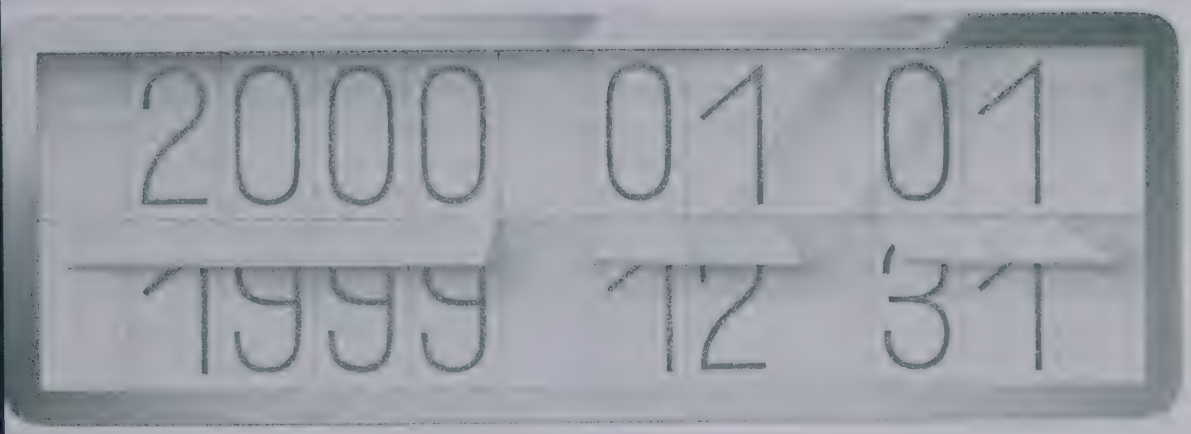
Large and small mass-heavy and light

A 40 cm^3 block of styrofoam has a mass of 1 g. A 10 cm^3 block of lead has a mass of 110 g. Which block is larger; which is heavier? Which has more mass; which has more volume?

The expression "large mass" generally conveys a large-sized object, but this may not be so. A large piece of styrofoam may have a smaller mass than a small piece of lead which would have the larger mass.

The greater the mass of an object, the greater the force of gravity pulling it down, hence the heavier it feels. It is therefore, quite correct to say, "This mass is heavy, that one is light," or "This is the heaviest mass in the box."

Here's relief for those who are never sure whether 4/7/75 means April 7, 1975, or July 4, 1975. Someday you may read that a sudden event occurred at 1976 08 19 16 34. Although this kind of configuration is not a part of the metric system, it may well be that metrication could present an opportunity for adopting numeric dating and the 24-hour clock on written schedules, notices of meetings, office memoranda, and so on.



251

Numeric dating

Information on numeric dating is given in ISO Recommendation R 2014. (ISO is the International Organization for Standardization.)

Numeric dating is simply a means of expressing the date by means of numbers. The year, month, and day, in descending order of magnitude, are expressed with 8 digits: 4 for the year, 2 for the month, and 2 for the day. For example, April 7, 1975, is expressed as 1975 04 07. Alternative ways of writing this numeric date are 1975-04-07 or 19750407.

If the recording of the century is not needed, numeric dating may omit the first 2 digits, as in 75 04 07 for April 7, 1975.

Numeric dating may, in time, become recognized practice. It is only mentioned here for general consideration, not necessarily for adoption. It is not a part of SI but is related in the sense that it involves an expression of measured time.

Numeric dating always puts the year first, then the month, then the day; the hour and the minute may be added.

The logic of this technique of recording a date becomes apparent when one is looking up past records that are arranged chronologically. One would first search for the year, then the month, and finally the day. The time in hours and minutes can be added, if desired. The time would be given in terms of the 24-hour clock.

252

24-hour clock

The following forms of indicating time on the 24-hour clock have disadvantaqes:
12h25—this shows the symbol only for "hours" not "minutes" and the spacing is incorrect;
1225—this leads to the incorrect practice of saying "twelve hundred twenty five hours".

Times in the day are expressed by four digits, commencing at midnight with 00:00, which is read as "zero hours." The first two digits represent the number of hours since midnight, and the other two digits represent the number of minutes in the last hour. The pairs of digits are separated by a colon since the two numbers represent the time in hours and minutes—two entirely different units of time. Times in the day are shown as follows:

Customary method	24-hour clock
6:30 a.m.	06:30
10:23 a.m.	10:23
12:00 a.m. (noon)	12:00
1:30 p.m.	13:30
4:00 p.m.	16:00
4:08 p.m.	16:08
11:30 p.m.	23:30
12:00 p.m. (midnight)	00:00 or 24:00

Note: Customary times in the afternoon are added to 12:00.

Digital clocks tend to show 00:00 for midnight, but 24:00 would also indicate the same time if no date is given. However, Tuesday at 24:00 would be the same as Wednesday at 00:00.

Time after midnight, such as 00:15, might be stated as "zero fifteen".

1975-04-07-15:30 indicates an event dated in 1975, on April the 7th at half past three in the afternoon.

We will probably continue to use such expressions as, "Meet me at four in the afternoon." However, there will be an increasing tendency to converse as follows.

"After lunch, the meeting will start at thirteen thirty."

"The committee did not start on time; they began at fourteen-o-eight."

"Let's meet tomorrow at sixteen hours." (or just"... at sixteen.")

"I generally go to bed at twenty-one fifteen."

The practice of expressing 15:00 as "fifteen hundred hours" (often used in the armed forces) is to be discouraged. There simply have not been "fifteen hundred hours" since midnight.

Note: Going metric does not imply that we necessarily switch to numeric dating or to the 24-hour clock.

260

Temperature interval

There is a marked difference between a specific temperature of 5°C and a temperature rise or drop of 5°C. Should there be a difference in the way these two quantities are written? In SI, the answer is *No*!

261

Preferred practice

In the past, a temperature change of 5 degrees, say from 11°C to 16°C, was often shown as 5 C°, that is, five centigrade degrees. This practice is to be discontinued. Such a *temperature change* is shown as 5°C and is read as "five degrees Celsius."

Since a *temperature* of 5°C is quite different from a *temperature change* of 5°C, the context must make it quite clear which of these is intended. See also 522.

270

Angles

The 360° circle of angular measure, inherited from the Babylonians, is likely to be around for a long time. If angular measure is changed, we will be required to alter all lines of latitude and longitude, and also revise the time zones around the earth.

271

Continued practice

Angles will, in common usage, be measured in degrees as in the past. The "decimal degree" is now *preferred* over the use of degrees, minutes, and seconds. For example, the use of 63.50° is preferred over the use of 63°30′, except possibly for maps.

No space is allowed between the numeral and the degree symbol: write 45°, not 45 °.

272

SI practice

Radians are often used in studies, such as trigonometry and rotational mechanics.

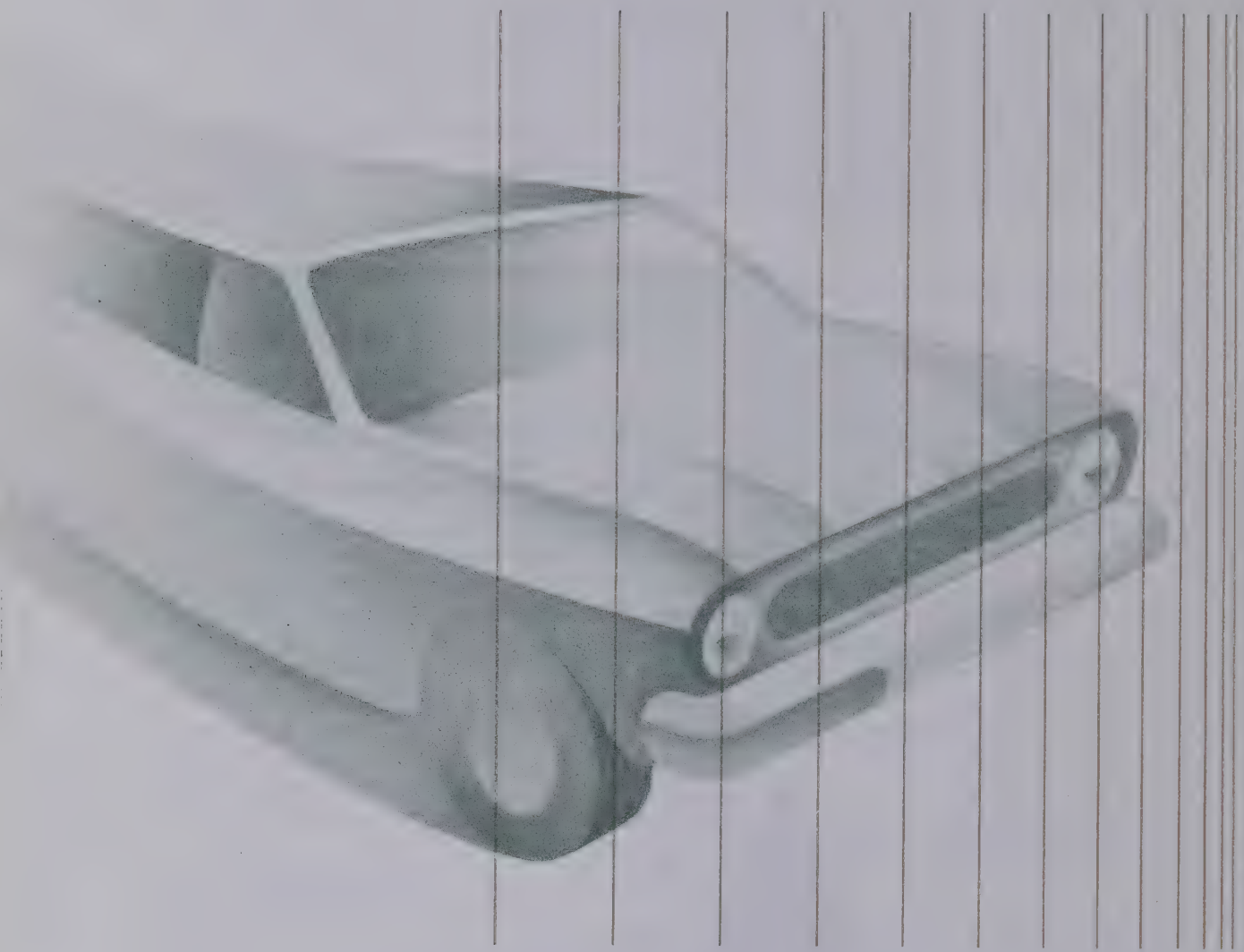
The radian (rad) is the SI unit for measuring plane angles. See 412.

Speed

The cruising speed of a Jumbo Jet is about 1000 km/h.

Speed limits will be stated in kilometres per hour (km/h) and are likely to change as follows:

Imperial	Metric
30 m.p.h.	50 km/h
50 m.p.h.	80 km/h
60 m.p.h.	100 km/h



"Speed" versus "rate"

If you can walk or jog a distance of 1 km in 10 min, at what speed are you moving?

Speed is defined as the distance travelled per unit time. Problems involving this concept occur in mathematics and science texts. The term "rate" is often used in place of the word "speed". "Rate" can refer to most changes that occur in time: rate of temperature drop, rate of volume flow, rate of angular motion, rate of price increase, and so on. Since "rate" can apply to so many applications of change, it is recommended that the term "speed" or "velocity" be used instead when distance changes with time.

"Velocity" generally includes the idea of direction and is therefore a little more comprehensive than "speed".

The terms or expressions we use often affect the corresponding formulas that are a part of solving measurement problems. The formula, $d = vt$, is more appropriate than $d = rt$ when used in speed or velocity problems. The symbol, r for rate, should be phased out. Symbols such as d for distance, v for speed or velocity, and t for time are called "quantity symbols" and are printed in sloping (italic) type. More of these are mentioned in 322 and 616.

Symbols for metric units, such as t for tonne, are printed in upright (roman) type.

"Classroom" speeds

In the classroom, students may determine speeds in metres per second (m/s). They may wish to compare these with metric highway speeds.

10 m/s = 36 km/h

Work done on units of speed may be enriched if the students create a chart showing the range of speeds from the imperceptible slowness of a glacier to the amazing rapidity of light.

The highest surface wind-speed known was on Mt. Washington at 371 km/h.

The fastest anyone has travelled is a speed of 39 897 km/h or 11.08 km/s. This was accomplished by Cernon, Young, and Stafford in Apollo X.

The earth is travelling around the sun at the fantastic speed of 107 240 km/h or 29.79 km/s.

The speed of light is 300 000 km/s or 300 Mm/s.

Immersion, comparison, or conversion

The height of Mt. Everest is 8840 m.

The length of the river Nile is 6670 km.

The greatest rainfall in 24 h occurred in La Réunion, Indian Ocean, and was 1870 mm.

During metrication, teachers may find themselves teaching the metric system to

a) young students who have had little or no exposure to imperial units–who therefore need not "unlearn" them;

b) young people who have only a nodding acquaintance with metric units, but who do not naturally "think metric"–they are at home with imperial units;

c) adults–in night school and community courses–who have been steeped in an imperial environment for decades and who may be reluctant to change.

No single policy is applicable to all categories of people who must learn the metric system. It will take a good number of years to phase out imperial units, making total metric immersion somewhat artificial, particularly for adults. Duality of metric and imperial units in our society must be accepted for some time to come.

Immersion

Immersion
"This stick (metre stick) is 1 m long. Our door is about 2 m high. The principal is about 180 cm tall."
~~We do not even hint that the principal is about 6 ft. tall!~~

In spite of the statements made in 290, it is recommended that the *classroom* provide as total a metric environment as is possible. For the majority, whether young or old, total *immersion* directly into the metric system is strongly advised. Through this technique, comparisons and conversions are not made between metric and imperial units; the two systems are not mixed within the same context. If imperial units are mentioned at all, they are treated alone, as members of an entirely different system.

It is strongly recommended that **total immersion in metric thinking, without reference to imperial measures, be adopted with respect to the learning and use of common metric units.**

Comparison

Comparison
"A length of 1 m is a little longer than 1 yd."

For a few students *comparison* may be helpful in the initial stages only. For example, they might be told that a tonne is a little greater than the imperial ton, or that $3.50/kg for meat is not more expensive than $1.60/lb. Comparisons should not involve numeric conversions and should be dropped as quickly as possible.

Conversion

Conversion
Don't read this unless you are desperate!
"1 m = 39.37 in."

For a limited time there may be the need for mathematical *conversion* between imperial and metric units for a small minority of people. A dietician may need to know that 1 Calorie = 4.19 kJ (kilojoules); a machinist, that 1 inch = 2.54 cm; and an electrician, that 1 hp = 746 W where hp denotes horsepower and W is the symbol for watts. At the end of this document (see 604 and 605) a few conversion factors are reluctantly given, but only for those who *must* use them.

Chapter 3

Basic rules of style

This chapter covers the style to be used in expressing metric quantities. The majority of rules given here are stated in a National Standard of Canada, called the *Metric Practice Guide*, CAN 3-001-02-73. It is available in separate English and French versions and may be purchased from Canadian Standards Association, 178 Rexdale Boulevard, Rexdale, Ontario, Canada M9W 1R3.

310

Common terms and symbols

Basic rules are set forth in this chapter. A few additional rules of a more complex nature are given in 590.

To ensure global uniformity in the adoption of metric practice, there are, in SI, various approved conventions governing the use of terms and symbols. The style to be used when expressing measured quantities is outlined in the following sections of this chapter and is based on international usage as interpreted for implementation in Canadian schools.

It is imperative that all schools subscribe to the principle of a single universal language of measurement as far as symbols are concerned. In particular, **the symbol for each unit is to be carefully noted and used accordingly.**

311

Pretest-what not to do!

According to correct metric practice each of the following has at least one error or deviation from preferred practice. When you have finished this chapter you will be able to spot all the mistakes.* Answers are given at the end of the chapter.

* All of these contain errors!

I bought 3 kilos of rump roast.
She used the 90cm. width of velvet.
The sun is 150,000,000 Kms away.
Brian drank 300 ML of milk.
Jane's temperature went up to 39 °C.
Bill has a mass of seventy-seven kilograms.

**There's at least one error in the parenthesis.

We need another 60 w bulb (the w denotes Watt).**
Carol added 45 c.c. of acid to the water.
John's height is 1¼ m.
He drove at 80 k.p.h.
$5 \cdot 7 = 35$
1 mile per hour = 1.609344 km/h.
It took 8l of paint to cover the walls.
She averaged 7.5 metres/second.
The symbol, km/h, means kilometres/hour.
The mass, m = 300 kg.
In 24 hr Grant's temperature dropped .8°C.
He parked about a meter ahead of the parking metre.

312

List of common metric terms

For a more complete list of terms and symbols, see 615.

The following alphabetic list includes the common metric units and prefixes mentioned in the first two chapters of this document. A few units, such as the minute and hour, are non-metric, but are listed because they are permitted for use with SI.

Some of these terms may be more common in teaching than in daily life.

Table 10 Common metric terms and symbols

Unit or Prefix	Symbol
centi (prefix)	c
centilitre	cl
centimetre	cm
cubic centimetre	cm^3
cubic decimetre	dm^3
cubic metre	m^3
day	d
deca (prefix)	da
decametre	dam
deci (prefix)	d
decimetre	dm
degree (angle)	°

Unit or Prefix	Symbol
degree Celsius	°C
gram	g
hectare	ha
hecto (prefix)	h
hectometre	hm
hour	h
kilo (prefix)	k
kilogram	kg
kilolitre	kl
kilometre	km
kilometre per hour	km/h
litre	ℓ
mega (prefix)	M
megametre	Mm
metre	m
metre per second	m/s
micro (prefix)	μ
micrometre	μm
milli (prefix)	m
milligram	mg
millilitre	ml
millimetre	mm
minute	min
second	s
square centimetre	cm^2
square decimetre	dm^2
square kilometre	km^2
square metre	m^2
tonne	t
year (annum)	a

What do the following symbols represent? Answers, stated in the plural, are given in the margin near 330.

a) Ml
b) mm^3
c) ms
d) ℓ/h
e) μg
f) Mg

Coined units and symbols

"The aircraft carries 80 000 kilos of fuel." Is this 80 000 kilograms or kilolitres? Confusion could be caused by loose usage of metric terms; hence, coined expressions and symbols are not to be used. "A kilo of meat" should be shown as "a kilogram of meat". This care should be taken no matter what the commodity. A price tag of $28 per kilo is written in poor form; it should be specified as $28/kl, or $28/kg, or $28/km, and so on.

Since SI symbols are international, abbreviations in measured quantities are taboo. Use m^2, not sq.m.; cm^3, not c.c.; km/h, not k.p.h.

Cubic metre has often been abbreviated cu.m. in English and m.cu. in French (mètre cube). Abbreviations for cubic metre vary from one language to another, but the international symbol, m^3, is understood globally.

320

Unit and quantity symbols

Note:
Section 320 and its sub-sections 321 and 322 refer to typeset printed material. It is hoped that printed textbooks will differentiate between unit and quantity symbols. Most typewriters do not have the capability to type both upright and sloping symbols. This distinction in symbols should not be expected in handwritten work. In general, the context should make the use of symbols quite clear.

Symbols for SI units are specified precisely; there is only one unit for each SI symbol. For example, the symbol, m, stands for "metre" and no other unit. It is true that m also represents "milli" but only when it is immediately in front of another letter. Symbols for SI units, then, are unique.

There is a need for another kind of symbol; that which stands for a quantity such as length, mass, time, speed, or density. Letters that represent such quantities are called "quantity symbols". They are not a part of SI and are not unique. For example, the letter "*m*" can stand for mass, magnetic moment, or molality.

Thus, while SI *unit symbols* are precise and unique, *quantity symbols* are used with greater flexibility. There is, however, an attempt to maintain some standardization in the use of quantity symbols and to distinguish them from unit symbols.

321

Unit symbols–upright letters

Upright (roman) type is used for symbols that denote metric units, for example:

l (or ℓ) for litre,
m for metre,
t for tonne,
V for volt.

Compare these four symbols with the first four shown in 322.

322

Quantity symbols–sloping letters

Sloping (italic) type is used to distinguish quantity symbols from unit symbols, for example:

l for length,
m for mass,
t for time,
V for volume.

Suggested quantity symbols are listed in Canada's *Metric Practice Guide*, pages 16 to 23. Here are some common quantity symbols.

Quantity symbols occur in formulae such as:

Area of rectangle
$A = lw$

Area of circle
$A = \pi r^2$

Volume of cuboid
$V = lwh$

Speed relationship
$d = vt$

More of these sloping symbols are given in 616.

Table 11 Some common quantity symbols

Quantity	Symbol
length	*l*
width	*w*
height	*h*
breadth	*b*
*distance	*d*
thickness	*d*
diameter	*d*
radius	*r*
area	*A*
volume	*V*
time	*t*
**temperature	*t*
speed	*v*
mass	*m*

*Not mentioned in the *Metric Practice Guide*, but suggested here for possible use in schools.

**The lower case *t* is suggested in the *Metric Practice Guide* for common temperatures expressed in degrees Celsius, and the upper case *T* for thermodynamic temperatures expressed in kelvins.

When there may be confusion between the symbols for time (t) and temperature (t), the Greek letter θ (theta) may be used to represent temperature.

If no confusion is likely to be caused, it may be convenient within a single problem or example to use a quantity symbol in both lower and upper case. For instance, r and R may represent the radii of two different circles.

Sloping symbols are useful in texts, particularly when a formula is used. This is illustrated by the following problem.

What is the volume of a room 15 m long, 8 m wide, and 2.5 m high?

Solution: $l = 15\text{ m} \quad w = 8\text{ m} \quad h = 2.5\text{ m}$

$$V = lwh$$
$$= 15\text{ m} \times 8\text{ m} \times 2.5\text{ m}$$
$$= 300\text{ m}^3$$

Decimal marker

330

Answers (see 312)
a) megalitres
b) cubic millimetres
c) milliseconds
d) litres per hour
e) micrograms
f) megagrams

Since the metric system is decimal in nature, numeric expressions in measurements show decimals in preference to mixed fractions.

In Canada, the decimal marker is generally shown as a point on the line, as in 73.6 kg. In many countries, a point is not used and confusion can result.

Varied practices

331

The mixed fraction $5\frac{3}{8}$ is shown as
5.375 in such countries as Canada and the US;
5·375 in the UK, Australia, New Zealand and elsewhere; and as
5,375 in most of Europe, South America, South Africa and many emerging nations.
At this time in Canada, this last example could be mistaken to mean five thousand three hundred seventy-five. Eventually, it is hoped that world-wide uniformity in the use of the decimal marker will be realized.

The decimal point

332

For the present in Canada, **a decimal fraction is generally indicated by means of a point on the line** (not in the raised position). In some literature the decimal marker is a comma. We must be aware of the possible use of either the point or the comma as the decimal marker.

The comma

333

Because a number like 5,375 is interpreted by some nations as five and three eighths and by others as five thousand three hundred seventy five, there is a firm international ruling as follows. The use of the comma to separate sets of three digits to the left of the decimal point is now to be discontinued; a space is left where we used to put a comma. A number like 56,384.29 is written as 56 384.29 and this grouping into sets of three digits applies to the right of the decimal point as well. For instance, the numeral 3.14159 should be shown as 3.141 59 and this practice should apply to all new textbooks published in Canada. If there are only four digits to the left or right of the decimal marker, the space is unnecessary except in a column with other numbers that show the space. See 343c.

340

Basic rules

The following are the basic rules of style governing the names of units and the writing of symbols and numerals when indicating measured quantities.

341

Rules governing names of units

The spelling "metre" should be used for the base unit of length.

a) The spelling of the names of units should be that shown throughout this style guide.

I gained a kilogram.
The force is half a newton.

b) The name of a unit commences with lower case (except at the beginning of a sentence).
Note: For the unit "degree Celsius" the modifier is capitalized.

A 1000 km distance is not called a kilokilometre; 1 Mm (megametre) is permissible.

c) Only one prefix is applied to a unit at a time. There is no hyphen between prefix and unit.

Speeds can be stated in metres per second (not metres/second).

d) If a compound unit involving division is spelled out, the word "per" is used.
A compound unit contains the names of two or more units.

Write kilowatt hour rather than kilowatt-hour.

e) If a compound unit involving multiplication is spelled out, it is unnecessary to use a hyphen.

342

Rules governing symbols

The symbol kg denotes kilogram in English, chilogramma in Italian, and quilogramma in Portuguese.

a) Abbreviations, such as sq. cm., should be avoided; they differ from one language to another, but SI symbols, such as cm^2, are the same in all languages.

The upright m denotes metre, whereas the sloping *m* may denote mass. If, for a rectangle, length $l = 5.0$ cm and width $w = 3.2$ cm, then

$$\text{area } A = lw$$
$$= 5.0 \text{ cm} \times 3.2 \text{ cm}$$
$$= 16 \text{ cm}^2.$$

b) In printed matter, symbols for units are shown in upright (roman) type, irrespective of the type shown in the rest of the text. (The cursive ℓ is an exception, but should be upright.)
This is to distinguish symbols for units from symbols for quantities which are printed in sloping (italic) type.

Write 180 cm rather than 180 centimetres.

c) Symbols should be used in place of full names when units are used in conjunction with numerals.

Twelve kilograms is shown as 12 kg (not 12 kgs).

d) Symbols are not pluralized.
The symbol s denotes second.

I am 154 cm tall and have a mass of 56 kg.

e) A symbol is not followed by a period (except at the end of a sentence).

The symbol for milliwatt is mW, for kilowatt, kW, and for megawatt, MW.

f) Symbols for prefixes are shown in lower case except for those that are greater than "kilo".

The symbol for watt is W; for newton, N, and for pascal, Pa.

g) Symbols for units named after individuals show the first letter in upper case.

Use m^2 and cm^3 (not sq. m. and c.c.)

h) Exponents 2 and 3 are used with symbols for units that are squared or cubed.

In measurement, km^2 means km × km. (This differs from algebra where km^2 means k × m × m.)
The sentence, "The symbol g denotes gram." shows better form than the sentence, "g is the symbol for gram."

i) Exponents apply also to the prefix attached to the unit symbol.
A prefixed symbol, such as km, is considered as a single entity.

j) Symbols should not be used to start a sentence.
To start a sentence with a lower-case letter is considered poor form.

The symbol km/h denotes kilometre per hour.

k) Compound symbols formed by dividing units contain a solidus (/) to indicate the division.
See also 590.

The symbol kW·h denotes kilowatt hour; N·m, newton metre; but these may be shown as kW.h and N.m in typing.

l) Compound symbols formed by multiplying units contain a dot to indicate multiplication.
The dot should be in the raised position in printed material, but may be on the line, particularly for typewritten work. See also 343(i).

Rules governing numerals

31 m, 5.2 s, 60 MW, 37°C, and 3×10^8 cm show the correct spacing between numeral and symbol.

a) A space is left between the last digit of a numeral and the first letter of a symbol.
Note: The degree symbol occupies the space when recording temperatures. For angles, such as 42°, no space is needed.

You need 6.4 m of cloth for your drapes.

b) A decimal fraction is indicated by means of a decimal marker on the line, and at present, in Canada, the marker is generally a point. In some literature, the marker is a comma.

Canada's area is 9 976 139 km^2.
1 mile = 1.609 344 km.
This is the year 1975.
1 cal = 4.1868 J
Column of numerals 56 113.74
9 825.36
12 377.40

c) Spaces, not commas, are left between groups of 3 digits to the left and right of the decimal marker.
The space is unnecessary if there are only 4 digits to the left or right of the decimal, unless such numerals are listed in a column with other numerals of 5 digits or more.

The pail holds 5.25 ℓ (rather than 5¼ ℓ).

d) Decimal fractions are generally preferred to common fractions.

3/4 = 0.75 (Do not write .75.)
800 g = 0.8 kg

e) A zero is placed to the left of the decimal marker if there is no other digit to the left.

My height is 164 cm (rather than 1.64 m).
The plywood is 6 mm thick (rather than 0.6 cm).
My height is 164 cm (rather than 1 m 64 cm or 1 m 6 dm 4 cm).

f) For simplicity, a decimal fraction may often be avoided in common use.

g) In general, only one unit should be used to express a measured quantity.

12 000 g is better shown as 12 kg. 3.21 mm is less complex than 0.003 21 m.
The distance from Ottawa to Toronto is 400 km; from Halifax to Vancouver, 5960 km; and from the North Pole to the Equator, it is 10 000 km.

h) In general, in the expression of any quantity, a prefix should be chosen so that the numerical value lies between 0.1 and 1000. However, when similar quantities are compared, it is better to use the same prefix for all items even though some values may fall outside the 0.1 to 1000 range.

Use 5×7 (not 5 · 7).

i) A dot must not be used as a multiplication symbol between numerals.

The rope is 28 m long (rather than "twenty-eight metres" or "28 metres").

j) In general, in the expression of numbers over ten, digits are preferred to fully spelled out words.

Corrections to the statements made in Section 311.

I bought 3 kg of rump roast.
She used the 90 cm width of velvet.
This could have been stated as 150 Gm, but the gigametre may not be well known. — The sun is 150 000 000 km away.
Brian drank 300 ml of milk.
Jane's temperature went up to 39°C.
Bill has a mass of 77 kg.
We need another 60 W bulb (the W denotes watt.)
Carol added 45 cm^3 of acid to the water.
1.25 m is permissible, but not preferred in this example. — John's height is 125 cm.
He drove at 80 km/h.
$5 \times 7 = 35$
1 mile per hour = 1.609 344 km/h.
It took 8 ℓ of paint to cover the walls.
She averaged 7.5 m/s.
or kilometre per hour. — The symbol, km/h, means kilometres per hour.
The mass, $m = 300$ kg.
In 24 h Grant's temperature dropped 0.8°C.
He parked about a metre ahead of the parking meter.

Part B

Chapter 4

The structure of SI

410

Kinds of SI units

SI was formally established by the General Conference of Weights and Measures in 1960. The Conference is often referred to as the CGPM from the French name, La Conférence Générale des Poids et Mesures.

The first 3 chapters of this guide have concentrated on common everyday units. In most of our experiences with measurement we won't need to be conversant with the structure of SI. However, for many educators, understanding the development of the system is necessary if they are to comprehend modern metric measures. This chapter gives a brief survey of SI, showing how the system is put together.

In SI there are 3 kinds of units:

a) base units,

b) supplementary units,

c) derived units.

Multiples and sub-multiples of these units are formed by the use of prefixes.

In addition, there are a few non-SI permitted units that are allowed for use with SI.

411

Base units

These are called "base units", not "basic".

There are 7 SI base units–the building blocks of the entire system. These were chosen arbitrarily for the convenience of creating a coherent system of measurement that will not only meet our daily requirements, but will also satisfy most of the needs of science and technology. The following table lists the 7 base units of SI.

Table 12 SI base units

Quantity	Unit	Symbol
Length	metre	m
Mass	*kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	**kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

The common units are
metre
kilogram
second

degree Celsius

*The kilogram is the only base unit that contains a prefix. The gram proved to be too small for practical purposes.

**The base unit of temperature is the kelvin, but in the everyday world the degree Celsius is used instead.

The kilogram was selected as the base unit of mass for SI, but only after it was well established in previous metric systems. Proposals to change the name "kilogram" to "kram", as well as other suggested names, have not yet been successful.

The ampere is used in electricity, the kelvin in thermodynamics, the mole in chemistry, and the candela in optics. Formal definitions of the base units are given in 606.

412

Supplementary units

The symbol for radian is rad and for steradian, sr.

There are 2 supplementary units, the radian and steradian. They are used for measuring plane and solid angles, respectively. Since their application is rather limited, further reference to these units is reserved for 607. In common practice, plane angles will continue to be measured in degrees. See 270.

Coherency

Examples of non-coherent units:
km/h (1 km/h = $\frac{1000}{3600}$ m/s)

ha (1 ha = 10 000 m²)

g/cm³ (1 g/cm³ = 1000 kg/m³)

These units, km/h, ha, and g/cm³, are related to the base units as shown above by some numeric factor other than one and are therefore non-coherent.

The principle of coherency may be stated thus: A unit is coherent if it is formed by multiplying and/or dividing base (and/or supplementary) units without involving any numeric factor other than one (1).

Examples:

a) The coherent SI unit of speed is formed by dividing one metre by one second, arriving at the metre per second (m/s).

b) The coherent unit of area is formed by multiplying one metre by one metre; we could call this unit the "metre metre", but it is named "square metre" (m²).

c) The coherent unit of density is more complex, formed by multiplication of metre × metre × metre, then division into kilogram; it is the kilogram per cubic metre (kg/m³).

Derived units

All coherent units in SI are called derived units. The derived units are said to be coherent with the set of base units. The property of coherency makes SI the simplest modern system of measures known to man. Coherency reduces mathematical calculations and simplifies inter-relationships between metric units. However, it is impractical, for instance, to always measure speeds in metres per second, never in kilometres per hour. In some applications, coherency gives way to practicability.

In SI, derived units are named in 2 ways; some have compound names, some special names.

Derived units with compound names

A derived unit with a compound name is one that contains two or more units in its name. Examples are "metre per second" and "kilogram per cubic metre". Those that include squares or cubes, such as square metre, are also compound. The following are some such derived units with compound names.

The derived units of *area* and *volume* are *square metre* (m²) and *cubic metre* (m³), respectively. Their derivation may be shown, using symbols, as

1 m × 1 m = 1 m² for the square metre, and

1 m × 1 m × 1 m = 1 m³ for the cubic metre.

The derived unit of *density* is the *kilogram per cubic metre* (kg/m³), since density = mass per unit volume. In SI, the approximate density of air is 1.2 kg/m³; water, 1000 kg/m³; and iron, 7900 kg/m³.

The derived unit of *speed* is the *metre per second* (m/s). A man, moving at

1 m/s, is walking at a very leisurely pace;

2 m/s, is jogging slowly;

5 m/s, is running steadily; and at

10 m/s, is close to record-breaking speed for the Olympic 100 m dash.

Acceleration is the rate at which velocity changes, hence the units are $\frac{m/s}{s}$ or m/s^2.

The double solidus, without brackets, is not permitted. That is, (m/s)/s is accepted but m/s/s is not.

Standard acceleration due to gravity is 9.806 65 m/s^2.

The derived unit of *acceleration* is the *metre per second squared* (m/s^2). It is used, for example, to measure the rate at which a car gains speed. If a traffic light turns green and a car reaches the urban speed limit (50 km/h or 14 m/s) in about 7 s, it accelerates at roughly 2 m/s^2. A falling stone gains speed at about 10 m/s^2.

There are many other derived units with compound names–names that show how they are formed from base units. The following table shows some of them. See also 611.

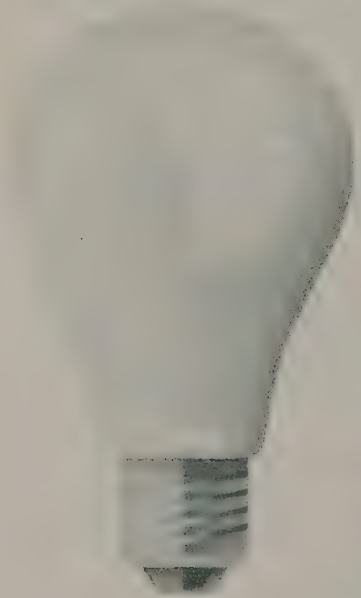
Table 13 Some derived units with compound names expressed in terms of base units

Quantity	Unit (Compound name)	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Speed	metre per second	m/s
Acceleration	metre per second squared	m/s^2
Density	kilogram per cubic metre	kg/m^3
Momentum	kilogram metre per second	kg·m/s
Angular momentum	kilogram metre squared per second	$kg·m^2/s$
Specific volume	cubic metre per kilogram	m^3/kg
Concentration	mole per cubic metre	mol/m^3
Luminance	candela per square metre	cd/m^2

Derived units with special names

It would be most unilluminating to ask for a "60 kilogram metre squared per second cubed light bulb" in a hardware store!

Some derived units are given special names for the sake of simplicity. For instance, the derived unit of power, expressed in terms of base units, is the "kilogram metre squared per second cubed". This is simply called the "watt", familiar to us through the use of electric light bulbs and appliances. The following are examples of some derived units with special names.



If you come across a metric unit called the sthene, remember that it is not a part of SI, but is equal to 1 kN.

The derived unit of *force* is called the *newton* (N), named after the English scientist, Sir Isaac Newton. The newton is roughly the force required by your hand when supporting 2 golf balls or a flashlight battery (one D cell). In SI, all forces are stated in terms of the newton, which is rather a small force. Multiples of this derived unit, such as the kilonewton and meganewton will occur in industry. If you can lift a 100 kg heavyweight boxer off the floor, you must exert a force of about a kilonewton (kN) to do

A dyne, a small unit of force, is also not a part of SI.
1 N = 100 000 dynes.

so. It takes a crane about a meganewton (MN) to hoist a 100 tonne (t) locomotive.

In terms of base units, the newton is a kilogram metre per second squared ($1\ N = 1\ kg \cdot m/s^2$).

The newton and all other derived units having special names are defined in 609.

Blaise Pascal was a French mathematician, scientist, and religious philosopher.

A dollar bill lying flat on a table exerts a pressure of about 1 Pa on the table.

The derived unit of *pressure* is called the *pascal* (Pa); it is equal to a newton per square metre ($1\ Pa = 1\ N/m^2$). This is a low pressure–that exerted by about 100 ml of sugar when spread evenly over the surface of a card table.

Multiples of the pascal, such as the kilopascal and megapascal, will be useful units of pressure. The air pressure required in a standard car tire is about 200 kPa, normal atmospheric pressure is about 100 kPa, and human blood pressure lies between 10 and 20 kPa.

James Prescott Joule, a British physicist, is known for his work on energy.

The derived unit of *energy* is the *joule* (J). It equals a newton metre (1 J = 1 N·m). If 2 golf balls are lifted through a height of 1 m, then 1 J of work has been done.

A young woman, climbing a one-storey stairway, expends about 1.5 kJ of energy, but if she had previously eaten a piece of apple pie, she would have absorbed about 1200 kJ, thus having plenty of energy to spare.

James Watt, a Scottish engineer, made steam power practicable. A 100 horsepower car is rated at 75 kW.

The derived unit of *power* is the *watt* (W), exactly one joule per second (1 W = 1 J/s).

The power rating of a car engine will be given in kilowatts, not horsepower.

Heinrich Rudolph Hertz, a German scientist, discovered electromagnetic waves.

The derived unit of *frequency* is the *hertz* (Hz), the SI name for "cycle per second". A frequency of 60 cycles per second is referred to as 60 Hz. "1010 on your dial" means a radio frequency of 1010 kHz, formerly called 1010 kilocycles per second.

More SI derived units with special names are formed in much the same manner as the newton, pascal, joule, watt, and hertz. For example, in electrical work,

1 C = 1 A·s
1 V = 1 J/C
1 Ω = 1 V/A

one coulomb = one ampere second
one volt = one joule per coulomb
one ohm = one volt per ampere

and so on, each unit being a product and/or quotient of other units that are already formed in the same manner from the set of base units.

The following table shows some SI derived units having special names. A complete list is given in 608.

Table 14 Some derived units with special names

Quantity	Unit	Symbol	Derivation	
Frequency	hertz	Hz	1/s	Reciprocal time
Force	newton	N	$kg \cdot m/s^2$	Mass times acceleration
Pressure	pascal	Pa	N/m^2	Force per area
Energy, Work	joule	J	N·m	Force times displacement
Power	watt	W	J/s	Energy per time
Electric charge	coulomb	C	A·s	Current times time
Electric potential	volt	V	J/C	Energy per charge
Electric resistance	ohm	Ω	V/A	Potential difference per current
Luminous flux	lumen	lm	cd·sr	Luminous intensity of source times solid angle of radiation

Note: The derivation of a unit is not necessarily unique. For example, the volt may be defined as 1 watt per ampere (W/A).

There are 15 derived units having special names and 13 of them are named after famous scientists. A list of such scientists appears in 610. See note at the end of 608.

In 415, the examples of compound units contained names of base units only. Derived units with compound names can also include units with special names along with base units, as in the "pascal second", a unit of viscosity. A list of derived units with compound names is given in 611.

SI multiples and sub-multiples

SI is made up of base, supplementary, and derived units; these could be used to express all required measurements. However, very large and extremely small measures would then involve cumbersome numbers. The distance from the sun to Pluto would have to be shown as 6 000 000 000 000 m and the mass of a bee's wing as 0.000 000 05 kg (or exponential notation would have to be used as shown in the margin.)

These measures are 6×10^{12} m and 5×10^{-5} g when expressed in exponential notation.

To avoid such numbers, decimal prefixes can be added to SI units; the above measures then become 6 Tm (tera-metres) and 50 μg (micrograms), respectively. The prefixes, "tera" and "micro", save writing numerous zeros.

Prefixes

The entire list of prefixes used in SI is shown in the following table.

Table 15 SI prefixes

Prefix	Symbol	Factor by which the unit is multiplied	
exa	E	**1 000 000 000 000 000 000**	$=10^{18}$
peta	P	**1 000 000 000 000 000**	$=10^{15}$
tera	T	**1 000 000 000 000**	$=10^{12}$
giga	G	**1 000 000 000**	$=10^{9}$
mega	M	**1 000 000**	$=10^{6}$
kilo	k	**1 000**	$=10^{3}$
hecto	h	**100**	$=10^{2}$
deca	da	**10**	$=10^{1}$
		1	$=10^{0}$
deci	d	**0.1**	$=10^{-1}$
centi	c	**0.01**	$=10^{-2}$
milli	m	**0.001**	$=10^{-3}$
micro	μ	**0.000 001**	$=10^{-6}$
nano	n	**0.000 000 001**	$=10^{-9}$
pico	p	**0.000 000 000 001**	$=10^{-12}$
femto	f	**0.000 000 000 000 001**	$=10^{-15}$
atto	a	**0.000 000 000 000 000 001**	$=10^{-18}$

Preferred prefixes

In an engineering drawing, the length of a metal block would probably be shown as 135 mm rather than 13.5 cm. In a calculation, where coherency governs the selected formula, the length would be indicated as 0.135 m, using the base unit in preference to a sub-multiple. For common use, the length of the metal block mentioned above might be stated simply as 13.5 cm.

In certain applications, particularly in technology, engineering, and science, some prefixes are used in preference to others. When written with base 10, the exponent of a preferred prefix is a multiple of 3. These prefixes increase by a factor of 1000, as is seen in the following examples.

mega $=10^{6}$ $=1000^{2}$
kilo $=10^{3}$ $=1000^{1}$
milli $=10^{-3}=1000^{-1}$
micro $=10^{-6}=1000^{-2}$

At one time, preferred prefixes were stressed in SI, but this is no longer the case. It is up to each economic sector to determine the use of prefixes according to its best interests.

In some literature, the prefix *myria*, meaning 10 000, is mentioned. This prefix is not permitted for use with SI.

In some parts of the world, the decilitre is commonly used in the wine industry. In Canada, it is expected that beverages will be available in containers showing specifications in litres and millilitres only.

In elementary and secondary schools, the emphasis that is placed on various prefixes must be determined by their use in the world outside the school. For instance, metre, decimetre, centimetre, and millimetre should receive equal treatment in discussion of the structure of the metric system, but their frequency of use in the classroom will be governed by relevant examples in the real world. The centimetre may not be used in engineering, but may be common in body measurements, clothing sizes, and elsewhere. Thus, if this turns out to be the practice in Canada, the centimetre will not be emphasized in auto mechanics, but it should be common in home economics. Further, it is unnecessary to use such expressions as decametre, hectogram, decilitre, and centivolt if there are no useful applications of these units in our society.

The following table shows the list of SI multiples and sub-multiples of the metre to illustrate the entire range of prefixes.

Table 16 SI units of length showing prefixes

Unit	Symbol	Meaning	Example
terametre	Tm	10^{12} m	Distance from sun to Saturn = 1.4 Tm
gigametre	Gm	10^{9} m	Sun's diameter = 1.4 Gm Earth to moon and back = 0.6 Gm
megametre	Mm	10^{6} m	Montreal to St. John, N.B.
kilometre	km	10^{3} m	Length of brisk 10 min walk
metre	m	1 m	Height of 3-drawer filing cabinet
millimetre	mm	10^{-3} m	Thickness of a dime
micrometre	μm	10^{-6} m	Size of bacteria
nanometre	nm	10^{-9} m	Length of oil molecule
picometre	pm	10^{-12} m	Wavelength of gamma rays
femtometre	fm	10^{-15} m	Diameter of a proton
attometre	am	10^{-18} m	???

The exametre (Em) and petametre (Pm) are not included in this table. See 421, table 15.

hectometre hm
decametre dam

decimetre dm
centimetre cm

In this table, where would you place the linear magnitude of the distance across Canada, our highest mountain, longest river, and tallest building?

See also Table 3 in 142.

Synonyms for some SI units

The cubic metre is the SI derived unit of volume. The cubic decimetre is called a sub-multiple since an SI prefix is added to the unit. The cubic decimetre consists of an SI unit and SI prefix and is therefore a member of SI. Strictly speaking, an SI unit is either a base unit, a supplementary unit, a coherently derived unit, or any multiple or sub-multiple of these, provided SI prefixes are used.

The tallest chimney in the world is International Nickel Company's stack in Sudbury, Ontario. Which of the following is its approximate height?
38 100 mm 38 100 dm
38 100 cm 38 100 m
How would this height be normally expressed?

Pioneer XI travelled 1440 million kilometres from the earth. How would you express this distance using a number under 1000?

Among the smallest of living organisms are mycoplasma; one strain has an estimated mass of 0.000 000 000 000 000 10 g. How would you express this mass using a suitable prefix?

The cubic decimetre is also called a "litre". The unit, litre, is not an SI unit; it is simply a convenient common name that has gained world-wide acceptance. Along with the litre, the millilitre, kilolitre, and similar non-SI units of volume are permitted for use with SI.

In actual practice, it rarely matters whether a unit is a member of SI or not, but the number of non-SI units permitted with SI is kept to a reasonable number to avoid proliferation.

The following, although non-SI units, are synonymous with certain SI units and may be used in their place.

litre in place of cubic decimetre
hectare in place of square hectometre
tonne in place of megagram

The *degree Celsius* is not a synonym for "kelvin" even though a temperature interval of 1°C equals an interval of 1 K. This is explained more fully in 520 to 523.

Non-SI units

430

Some non-SI metric units, such as the litre, hectare, and bar, are permitted for use with SI under certain conditions as indicated in the next section. In fact, some totally non-metric units are also permitted, such as the hour, the astronomical unit, and the nautical mile. Naturally such units should be kept to a minimum.

Permitted units

431

There are no international symbols for week or month.

Some units of measurement outside SI have been used on a world-wide scale and will continue to be accepted for use along with SI.

Permitted for universal use
minute, hour, day, year
degree (for angles)
litre
tonne
degree Celsius

See 612 for a more detailed table on permitted units and their symbols.

Some units are allowed for specialized applications.

Permitted in specialized fields
hectare
astronomical unit
parsec
electronvolt
unified atomic mass unit

Canada's "Metric Practice Guide" puts the hectare in the "for a limited time" category. However, it seems probable that the hectare will be a permanent replacement for the acre.

It may be assumed that the kilowatt hour will eventually be replaced by the megajoule.

Some units will be in use for a limited time only and will eventually be phased out. The time schedule for discontinuing these units depends on global usage in such fields as navigation and meteorology and will likely require international agreement. Such timing is not known and therefore cannot be given in this guide.

Permitted for a limited time
nautical mile
knot
millibar
standard atmosphere
kilowatt hour

Metric units not to be used

See 613 for more details on metric units that are not to be used.

The following units, although members of some former metric system, are among those that are not to be used with SI. If these are in use in the schools they should be phased out as soon as is feasible.

micron
angstrom
kilogram-force (or kilopond)
dyne
*calorie and Calorie
erg
millimetre of mercury (or torr)
stere
maxwell
gauss
oersted

*Final decision in Canada on the replacement of the Calorie by the kilojoule is pending.

Part B

Chapter 5

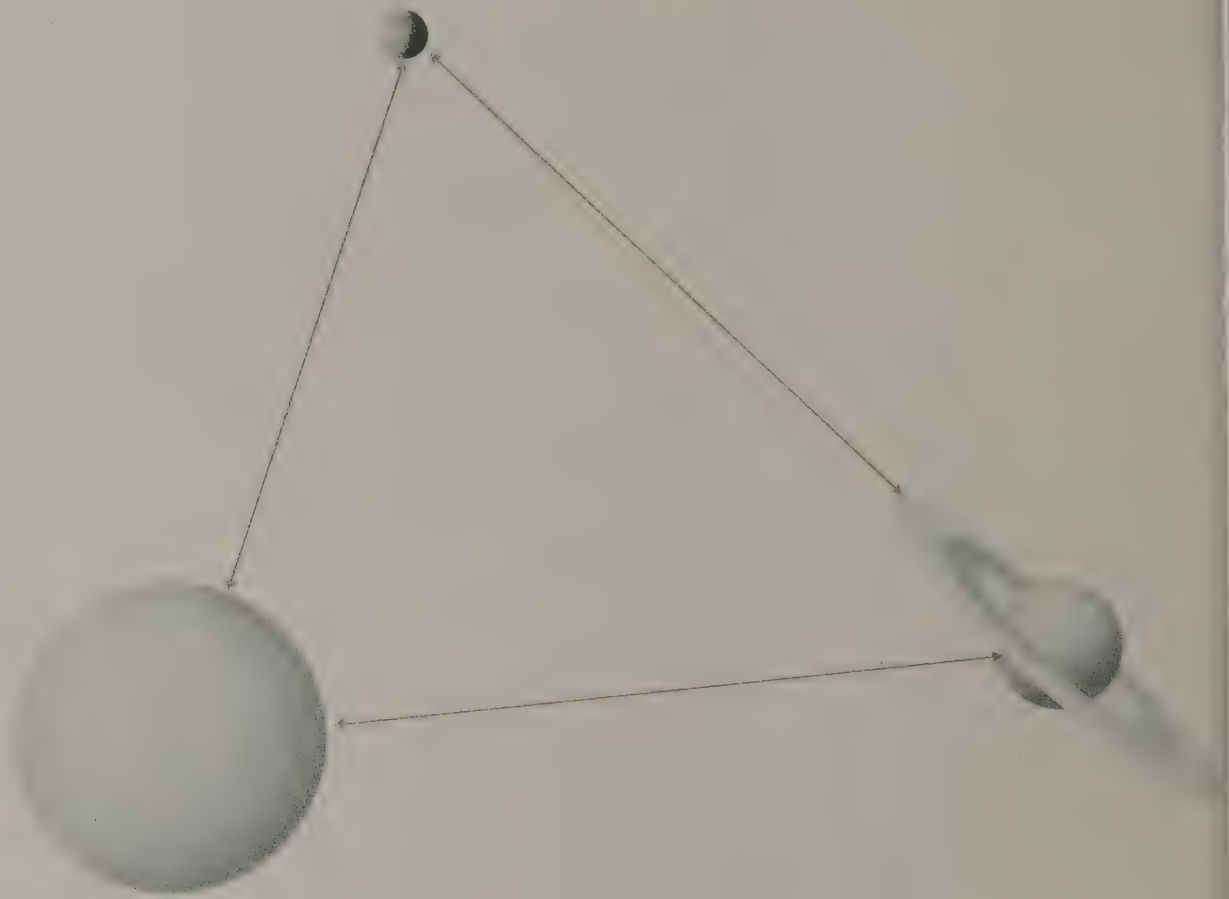
Specialized features

This chapter deals with particular points relating to the minimum level as outlined in Chapter 4. In general, the content is of a fairly specialized nature, relating to work frequently covered in secondary schools.

There is only one kind of kilometre, the one that is 1000 m in length. In SI each unit is unique, exactly defined, and universally accepted.

*The exametre may become the longest SI linear unit.
See 421 and 422.

The terametre* is the longest SI unit of length, but is too short for stellar astronomy. What is used to measure very large distances to stars way beyond a terametre? In navigation, there has been a nautical mile, different in length from the land or statute mile. Will there be two kinds of kilometres? What will replace the angstrom?



Astronomical distances

511

In astronomy, the unit of distance called the *astronomical unit* (with abbreviation AU in English and UA in French –no international symbol exists) will continue in use as in the past, except that it will be defined in terms of metric units rather than imperial. 1 AU = 149.600 Gm, the approximate distance between the earth and the sun. This unit is used for measurements of distance, normally confined to the solar system.

Distances of some stars from the earth.

Rigel A	250 pc
Betelgeuse	150 pc
Arcturus	11 pc
Vega	8 pc
Alpha Centauri	1.3 pc

The *light year* is the distance that light travels in a year. The symbol, ly, is often used for light year but is not an officially recognized symbol. 1 ly = 9460.5 Tm (approximately) or a little under 10 000 billion kilometres. The nearest star is more than 4 ly away.

The *parsec* (pc) is the distance at which a base line of 1 AU subtends an angle of one second. 1 pc = 30 857.2 Tm (approx).

Nautical measures

512

The nautical mile is based on the geometry of the earth–the mean length of one minute of arc of a great circle of the earth–and cannot be rounded off to a convenient number of metres, like 2000 m.

By the way, 1 sea mile = 1000 fathoms. Few people realize that we had a "kilofathom".

The international *nautical mile* is defined as exactly 1852 m, about a metre shorter than the imperial nautical mile. It is expected to be used in navigation for some time. The *knot* is a speed of one nautical mile per hour and is therefore equal to 1.852 km/h. The abbreviations n. mi. and kn are sometimes used for nautical mile and knot, but these are not official symbols.

Depths, in navigational waters, are measured in metres and tenths of a metre in place of fathoms.

Measurements in technical areas

513

Note: "micrometre" is a unit of length; it is pronounced with the accent on the first syllable and ends with "re" spelling; "micrometer", an instrument for measuring small dimensions, is pronounced with the accent on the second syllable and ends with "er" spelling.

A "thou" is slang for one thousandth of an inch.

The majority of linear measures in technical work will be stated in *millimetres* and *metres*. In machine design, drafting, building construction, and so on, dimensions under a metre or two will probably be expressed in millimetres and larger dimensions in metres. For precision work the *micrometre* is used; 1 "thou" or 1 mil = 25 μm (approx). If work has been machined to tolerances in terms of thous, metric conversion will demand similar work to a tolerance of 25 μm.

Very small distances

514

A wavelength of 6000 Å in the orange region of the spectrum is shown as one of 600 nm.

The *micron* is to be replaced by the micrometre (μm). They are both the same length, but the micron and its symbol "μ" are to be discontinued.

The *angstrom* (Å) is now an obsolete unit and is being replaced by the nanometre (nm). 10 Å = 1 nm.

520

Temperature

An interval or unit of 1 K = an interval or unit of 1°C, but a temperature of 1 K is very much lower than a temperature of 1°C. Care must therefore be exercised when using the Kelvin and Celsius scales.

521

The Kelvin scale

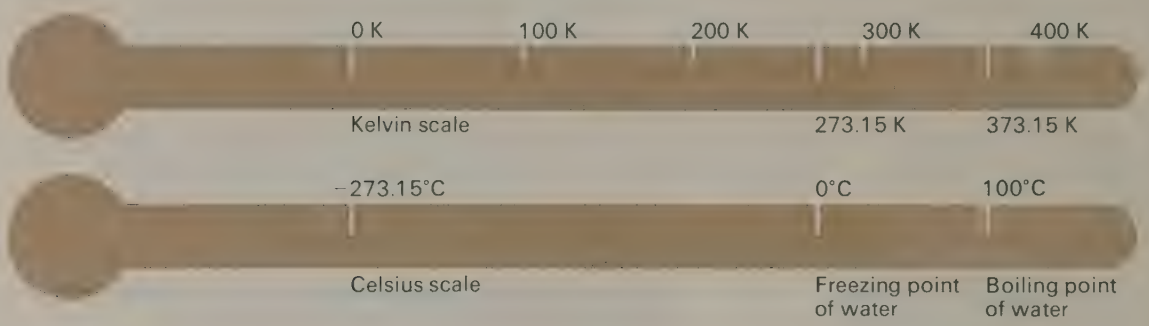
Lord Kelvin (William Thomson) was a British physicist and inventor.

0 K means "zero kelvin" and is quite O.K. for scientific use.

The SI base unit of thermodynamic temperature, the *kelvin*, is used in certain fields of science. The Kelvin scale (sometimes called the absolute scale) is very useful to the chemist, for instance, in the study of the gas laws. There are no negative readings on the Kelvin scale since the lowest possible temperature, −273.15°C, is called 0 K or absolute zero.

The freezing point of water is 273.15 K and the boiling point is 373.15 K; these temperatures correspond to 0°C and 100°C.

A temperature such as 310 K is read as "310 kelvins"; the degree symbol is not permitted with the K for kelvin. The degree symbol must be used in °C, as C alone means coulomb.



522

Temperature intervals

The individual units on both the Kelvin and Celsius scales are equal. That is, a change of 1 K = a change of 1°C. The symbols, K and °C, are used to denote temperature intervals as well as particular temperatures. Actually all temperatures are intervals above or below some arbitrary level.

This is comparable to changing the height of a tower from 295 m to 320 m, a change of 25 m. The temperature in the centre of a thermonuclear fusion bomb is of the order of 400 MK (megakelvins).

If the temperature of water changes from 295 K to 320 K, the increase is 25 K. The context must identify whether the quantity is a temperature or a temperature interval.

The reverse symbol, C°, is not used to denote temperature intervals in the Celsius scale as has often been the practice in the past. See 260.

523

Derived units involving the kelvin

Science teachers must make a careful examination of changes that SI will bring. These changes will then need to be implemented rather cautiously and at the appropriate time in Canada's program of metric conversion.

In SI, the derived unit for specific heat is the *joule per kilogram kelvin*. The symbol is J/(kg·K). The specific heat capacity of water is about 4200 J/(kg·K) replacing the former 1 cal/(g·°C), since the calorie is not permitted for use with SI.

This kind of change will affect the solution of introductory heat problems in secondary school science. A new look at curriculum development will be required even for those who have been teaching the metric system for years.

Wherever "kelvin" turns up in a derived unit and is used to indicate a temperature interval, it may be replaced by "degree Celsius". Thus the symbols J/(kg·K) and J/(kg·°C) are equivalent.

A paperweight will continue to be called a paperweight.

As has been mentioned, in 134 and 242, the term "weight" is ambiguous in meaning. It is therefore recommended that "weight" be used with discretion and that a clear distinction be made between "mass" on one hand and "force of gravity" on the other.

531

Mass

The mass of the earth is about 6×10^{21} t.

The world's record cabbage had a mass of 43.5 kg.

In SI, units of mass always contain the term "gram". The "tonne", a synonym for megagram, is an exception. Whenever "gram" or "kilogram" are seen, the attribute that has been measured must be mass. These units are not used in SI to express forces of any sort whatever.

532

Force of gravity

In referring to the force of gravity acting on a given mass, the word "weight" should be avoided because of its ambiguity. The expression "force of gravity" should be used, and this should always be expressed in terms of the *newton*, *not* the kilogram-force or kilogram-weight.

With the attention given to space flights, the distinction between "mass" and "force of gravity" is increasingly relevant to students and, in this context, emphasis is bound to be placed on this matter in education.

There is a 9.80 N (approximate) downward pull of gravity on every kilogram mass on the surface of the earth. On the moon the pull is only about 1.60 N/kg.

It may be shown (see 614) that a man whose mass is 80.0 kg experiences a force of gravity of 784 N on the Earth, but only 128 N on the moon. Up there, he is much lighter, but his mass—his quantity of matter—remains unchanged; it is still 80.0 kg.

To say that he weighs 80 kg is most misleading. *If mass is meant*, and mass does not change, then we must say that he weighs 80 kg on the moon while admitting that he is much lighter. This seems contradictory. *If force of gravity is meant*, then we must say he weighs about 13 kg on the moon, but 13 kg is supposed to denote mass and this is not supposed to have changed. This kind of dilemma must be avoided. The recommended solution is to refer to *mass* when mass is intended and to *force of gravity* when the gravitational pull is under consideration.

Will "weight watchers" become "mass minders"?

For young students the distinction between the terms "mass" and "weight", as they hear them in everyday use, is generally not important.

Teachers, however, should introduce the word "mass" in relation to grams and kilograms, without making a serious issue of the weight dilemma. Educators must be sensitive to the reactions of students and society who will often use and hear the term "weight".

In physics courses, a clear distinction must be made between "mass" and "force of gravity". It is recommended that the term "weight" be avoided.

533

The newton

Since forces are measured in newtons in SI, this will have an effect on problems in which forces are involved. A sample problem may illustrate this point.

A 6.0 kg square slab of steel, 20 cm by 20 cm, rests on a table. What is the pressure exerted by the slab on the table? (Pressure equals force per unit area.)

On every object on the earth's surface there is a gravitational force of 9.8 N/kg (approximately).

Area of contact = A = 20 cm × 20 cm = 0.20 m × 0.20 m = 0.040 m^2

Force exerted = F = 6.0 kg × 9.8 N/kg = 58.8 N

1 N/m^2 = 1 Pa

$$\text{Pressure} = p = \frac{F}{A} = \frac{58.8\ \text{N}}{0.040\ \text{m}^2} = 1470\ \text{Pa} = 1.5\ \text{kPa (approx)}$$

This kind of problem illustrates the need to consider changes in science courses.

Density

540

The most common unit of density has been the *gram per cubic centimetre* (g/cm^3); it is now probable that the derived unit of density, *kilogram per cubic metre* (kg/m^3), will become more prominent. So what is the density of water, aluminum and so on?

Units of density

541

The density of water is about 1000 kg/m^3.

The density of aluminum is about 2700 kg/m^3.

1 g/cm^3 = 1000 kg/m^3

This has been proposed by the American National Metric Council.
1 kg/m^3 = 1 g/ℓ

The density of nitrogen is 1.25 kg/m^3, glycerine, 1260 kg/m^3, silver, 10 500 kg/m^3.

Besides the kilogram per cubic metre, there are other density units that may be used for their convenience in certain applications. Some of these are the gram per cubic centimetre (g/cm^3), gram per millilitre (g/ml), kilogram per litre (kg/ℓ), and tonne per cubic metre (t/m^3).

These units are equivalent to one another and each unit is 1000 times as great as the kilogram per cubic metre.

It seems unnecessary to have such a variety of expressions or units for density. Since simplicity is the keynote of SI, it has been suggested that, unless it is very inconvenient, all densities be expressed in kilograms per cubic metre (kg/m^3). Its equivalent, the gram per litre (g/ℓ), is also suggested, but only for fluids and particulate matter such as sugar, salt, peas, and so on. The practice to be adopted in Canada remains to be seen.

Roughly speaking, densities of gases are of the order of 1 kg/m^3; those of liquids, 1000 kg/m^3; and those of metals, 10 000 kg/m^3.

Relative density

542

The relative density of aluminum is 2.7 on the basis of information given above.

Relative density is a ratio and has no units; it is always just a number.

The terms "specific weight" and "specific gravity" should be replaced by the term "*relative density*". Mercury has a relative density of 13.6, meaning that it is 13.6 times as dense as water. Water is implied as the reference substance for liquids and solids, and air the reference for gases, unless indicated otherwise.

The term "specific"

543

The specific volume of hydrogen is 11 m^3/kg.

Specific latent heat of fusion of ice at 0°C = 334 kJ/kg*; that of vaporization of water at 100°C = 2250 kJ/kg*.

*These could also be stated as 334 J/g and 2250 J/g. However it is more acceptable to use the base unit of mass, the kilogram, in the denominator of the unit.

Often, the term "specific" in the name of a quantity, such as specific volume or specific energy, means "per unit mass"; that is, "per kilogram" in SI. Some such quantities are shown as follows to illustrate this nomenclature.

Volume is measured in	m^3
Specific volume	m^3/kg
Energy	J
Specific energy	J/kg
Heat capacity	J/K or J/°C
Specific heat capacity	J/(kg·K) or J/(kg·°C)

Note that specific volume (volume per unit mass) is the reciprocal of density (mass per unit volume).

550

Pressure, stress

In former metric systems, the most common mechanical unit of pressure has been the kilogram-force per square centimetre (kgf/cm^2). This unit is not coherent and is not permitted in SI. The change to the *pascal* as the unit of pressure is one that we should expect as Canada adopts SI. Other pressure units, such as the millimetre of mercury and the bar, are probably going to be replaced in the future, but the timing has yet to be determined.

551

Replacing former pressure units

The highest barometric pressure on record was in Siberia, 108.38 kPa; the lowest was north-west of Guam in the Pacific, 87.7 kPa.

In some countries, tire pressures are now stated in kilopascals.

The kPa is expected to be used in Canada for pneumatic and hydraulic pressure in industry and home: as in tires, water pressure, auto brake lines, and so on.

There does not seem to be any immediate prospect of weaning the medical profession from the measuring of blood pressure in millimetres of mercury.

The *bar* and *millibar* are not SI units but are likely to be used temporarily in meteorology. They should not be used on new equipment. 1 bar = 100 kPa and 1 mbar = 100 Pa.

The *standard atmosphere* (atm) equals 101.325 kPa, but for low-accuracy work this may be taken as 100 kPa. The millimetre of mercury or the torr are each about 133 Pa; these should not be retained.

Gradually, non-SI units of pressure should be replaced by the pascal, but it will take time to phase out old equipment, barometers, pressure gauges, and textual material. New items should show SI units in the near future.

Mechanical properties such as tensile strength, modulus of elasticity, shear strength, compression strength, flexural strength, and adhesion (shear method) are to be expressed in multiples of the pascal, such as the kPa, MPa, and GPa.

Certain applications in technology involve forces on very small areas and the pressure could be expressed in newtons per square millimetre (N/mm^2), but this is equivalent to the megapascal. It seems reasonable to expect the use of the MPa in preference to the N/mm^2; this would simplify comparisons.

552

Avoiding the kilogram-force

The kilogram-force (kgf) is not a part of SI and is to be avoided in units of pressure such as the kilogram-force per square centimetre.

$$1\ kgf/cm^2 = 9.8\ N/cm^2 \text{ (approx)}$$
$$= 9.8 \times 10^4\ N/m^2$$
$$= 98\,000\ Pa$$
$$= 98\ kPa$$

So the kilogram-force per square centimetre (kgf/cm^2) should be replaced by 100 kPa (approx.).

One purpose in switching to the pascal for all pressures and stresses is to simplify comparisons. Wherever feasible, all pressures should be expressed in terms of the derived unit, its sub-multiples, and multiples. The following table illustrates this point.

Table 17 Pressures and stresses in terms of the pascal

Example	Pressure
Very high vacuum electronic tube	1 mPa
Pressure drop across air duct filter	150 Pa
Air pressure 10 km high outside jet liner	25 kPa
Cabin pressure inside jet liner	75 kPa
Atmospheric pressure at sea level	100 kPa
Standard car tire pressure (gauge)	200 kPa
Bicycle tire pressure (gauge)	400 kPa
Oxygen gas bottle pressure, maximum (gauge)	24 MPa
Hydraulic jack (gauge)	up to 200 MPa
Yield strength: structural steel	300 MPa
Modulus of elasticity:	
aluminum	70 GPa
yellow brass	100 GPa
mild steel	200 GPa

Another advantage in using the pascal is its coherent relationship to other units. For example:

$$1\ \text{Pa} = 1\ \text{N/m}^2$$
$$= 1\ (\text{N}\cdot\text{m})/\text{m}^3$$
$$= 1\ \text{J/m}^3$$

Hence, the pascal is equivalent to a joule per cubic metre, showing the equivalence between pressure and energy per volume in terms of SI derived units–a useful relationship in science.

We will soon be able to stop worrying about all those Calories in a banana split; at least, the demise of the Calorie is under consideration. But SI has its replacement, the kilojoule, with which we will have to contend when dieting.

The calorie

561

The international cal=4.1868 J.
The 15°C cal=4.1855 J.
The thermochemical cal = 4.184 J.
The 4°C cal=4.2045 J.
The mean cal=4.1897 J.

The calorie (cal)—the one with the lower case "c"—is a metric unit, but is not permitted for use with SI. Its definition is based on the temperature change of a given mass of water. There have been at least 5 such calories, all different, and now obsolete. The calorie has had no simple relationship with other energy units used in mechanics and electricity, so awkward conversions have had to be made between the various energy units.

In food chemistry, the calorie proved to be too small for convenience, so the kilocalorie (kcal) became known as the large calorie or the Calorie with upper case "C" and symbol Cal. It is Calories that are used in diet charts, though they are often incorrectly called "calories". With all this confusion and lack of coherency, the calorie and Calorie are not acceptable for use with SI and should be phased out—in time.

The joule

562

If the numbers on new diet charts are larger we may be more careful to keep those "kJ's" down.
A chocolate milk shake, 350 ml, has 2200 kJ.
Two half peaches with liquid, canned in syrup, have 380 kJ.
One piece of fudge, 3 cm square, has 480 kJ.
Three slices of Canadian bacon have 840 kJ.
A fried chicken thigh and drumstick have 1030 kJ.
A hamburger with bun has 1550 kJ.
Ten medium French fries have 650 kJ.
One scrambled egg has 460 kJ.
15 ml of unsweetened whipped cream has 125 kJ.
A piece of cherry pie with 10 cm arc and 11 cm radius has 1400 kJ.

Eventually, it is expected that most, if not all quantities of energy will be expressed in terms of *joules* (J).

The energy content of a meal containing 380 Cal is equivalent to about 1600 kJ since 1 Cal = 4.2 kJ (approx). This means that new diet charts will require some getting used to and we'll be concerned about watching those "kJ's" instead of Calories.

The "small" calorie is related to the joule as follows: 1 cal = 4.2 J (approx).

In science courses, the joule should be used to state most quantities of energy. In particle physics the electronvolt (eV) is permitted for use with SI as a useful unit of energy.

Electrical energy may continue to be measured by the kilowatt hour for some time. This custom should change when old meters are replaced. In the meantime, it would be quite reasonable to receive the electric bill based on so many ¢/MJ instead of so many ¢/kW·h. (1 kW·h = 3.6 MJ.)

Coherency is apparent when one realizes the various combinations of other units that are equivalent to the joule.

Table 18 Some units equivalent to the joule

Equivalent Unit	Corresponding Formula	Kind of Energy
1 J = 1 N·m	$E = Fd$	mechanical energy (work done)
1 J = 1 W·s	$E = Pt$	electrical energy
1 J = 1 kg·(m/s)^2	$E = \frac{1}{2}mv^2$	kinetic energy
1 J = 1 kg·(m/s^2)·m	$E = mgh$	gravitational potential energy
1 J = 1 Pa·m^3	$E = pV$	fluid energy (gas laws)
1 J = 1 V·A·s	$E = VIt$	energy of electric current
1 J = 1 C·V	$E = QV$	energy of charged conductor

570

Other quantities

There are a great number of additional quantities that require measurement or study in the curriculum. It is not feasible in a document of this kind to cover all cases, but the following brief sections mention a few topics for consideration.

571

Rotational motion

LP records have a rotational frequency of about 33 r/min, that is about 0.55 r/s or 2000 r/h.

Rotational frequency is the number of revolutions per unit time. This should be stated, for example, as 120 r/min or 2 r/s. This last example might be shown as $2\ s^{-1}$, but 2 r/s is accepted, with the understanding that "r" does not represent a unit of measure. The revolutions are events that are counted (not measured) in a measurable unit of time. Rotational frequency is not stated in hertz.

Angular velocity is measured in radians per second (rad/s) and angular acceleration in radians per second squared (rad/s^2).

572

Flow

Niagara Falls has an approximate flow of 5000 m^3/s which is about 18 billion litres per hour. This rate of flow could be stated as 18 Gl/h (gigalitres per hour).

Volume rate of flow = volume per unit time. The SI derived unit is the cubic metre per second (m^3/s), but other variations, such as litre per minute (ℓ/min), are permitted. Sometimes mass is used, in which case the derived unit would be the kilogram per second (kg/s).

573

Gasoline consumption

You are probably anxious to know what mileage these cars get. The larger car gets only 14 miles per gallon and the smaller car, 35 miles per gallon. (See 604, the last topic.)

We are likely to express gas consumption by cars in litres per hundred kilometres, that is, the amount of gasoline it takes for the car to travel 100 km. For instance, a large car may consume gas at 20 ℓ/100 km, while a smaller car may only require about 8 ℓ/100 km. The lower the number of litres, the less gas you consume. This way of stating fuel consumption is prevalent in Europe and other metric areas of the world.

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Concentration

One method of stating the concentration of substance A in substance B is to state the ratio of masses. For example:

$$\frac{\text{mass of cocoa}}{\text{mass of milk}} = \frac{2\ \text{kg}}{25\ \text{kg}}$$ for a large crowd

or $\frac{20\ \text{g}}{250\ \text{g}}$ for an individual = 8%

Comparison by volume is perhaps more common. For example:

$$\frac{\text{volume of sugar}}{\text{volume of water}} = \frac{15\ \text{ml}}{250\ \text{ml}} = 6\%$$

Generally, when the units of comparison are the same, the concentration is preferably stated as a percentage. When the units are different they must be stated. For example: Concentration of wallpaper paste to water = 150 g/ℓ.

Note that 1 mol/m^3 is only 0.001 mol/ℓ.

In chemistry, the derived unit for molar concentration is stated in moles per cubic metre (mol/m^3).

Mass per length or per area

575

This page is printed on paper which has a "grammage" of 100 g/m².

A property of a wire or cable is often specified as the mass per unit length. The derived unit would be kilogram per metre (kg/m).

Sheet materials, such as paper, glass, and so on, are specified in terms of mass per unit area. The derived unit is kilogram per square metre (kg/m²).

Moment of force, torque

576

Note:
Since the force and displacement vectors are perpendicular, the N-m is not multiplied to obtain J for joule.

The derived unit for moment of force or for torque is the *newton metre* (N·m). When the principle of moments is taught, care should be taken to express the forces in newtons, not in gram-forces. This presents a challenge to teachers and may be partially solved by adjusting the order of topics in the curriculum. In any event, newton scales should be used to determine the forces involved. Science teachers are advised of the need to adhere to the principle of coherency if SI is to reap maximum benefit.

580

Terms and symbols

In 312 there is a list of common units and prefixes with their symbols. In Chapters 4 and 5 many more have been given. There is an alphabetic list of units in 615, which includes most of the units mentioned in this document except those imperial units that are not to be used with SI.

The difference between unit symbols printed in upright (roman) type and quantity symbols printed in sloping (italic) type has been mentioned in 320. Some common quantity symbols are listed in 322. A more complete list is given in 616.

590

Additional rules of style

This section is an extension of 340 in which lists of basic rules of style are given. The following rules can now be stated, since we can use examples to illustrate them.

The derived unit of acceleration is written preferably as m/s^2 or $m \cdot s^{-2}$; (m/s)/s is acceptable; m/s/s is not.

a) The solidus, as a symbol of division, must not be repeated in the same expression unless ambiguity is removed by the use of brackets.

Metres per second may be shown by the symbol, $m \cdot s^{-1}$. Note: ms^{-1} would mean a reciprocal millisecond.

b) Division by a unit may be shown by means of a negative exponent. In such cases the dot should also be used to avoid misunderstanding.

Use km/s rather than m/ms. Use MPa rather than N/mm^2. But MJ/kg is preferred to kJ/g.

c) When a unit is formed by division, the prefix, if any, should be attached to a unit in the numerator. An exception occurs when the base unit "kilogram" appears in the denominator.

Exceptions to this rule may be accepted in rare cases.

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Part C

Chapter 6

Reference material

This chapter is in the nature of an appendix and is intended for reference purposes. The numbering of each section does not follow the pattern adopted in the rest of the text. The sections are merely numbered in succession, starting with 601.

Old-fashioned units and imperial conversions

Here is a brief indication of measures as they have been in the past. Although these units are primarily of historic interest, you may recognize the continuance of a few in our modern world. SI is designed to abolish many of the problems inherent in such a welter of confusion.

Table 19 Some obsolete or old-fashioned units

Obsolete unit	Type of quantity	Equivalent value	Practical application or commodity
bag	volume	5 bu	potatoes
bag	mass	98 lb	flour (US)
bag	mass	364 lb	wool (UK)
barge	mass	21½ tons	coal
barony	area	4000 acres	land
barrel	volume	26½ gal	tar
barrel	volume	32 gal	herrings
barrel	mass	112 lb	gunpowder, raisins (UK)
barrel	mass	120 lb	candles, potatoes (UK)
barrel	mass	256 lb	soap (UK)
bolt	length	16 yd	wallpaper (US)
bolt	length	40 yd	cloth (US)
box	mass	22 lb	Malaga raisins
box	mass	25 lb	Jordan almonds
cask	mass	140 lb	cocoa
cask	mass	200 lb	nutmegs
chest	volume	125 gal	olive oil
chest	mass	200 lb	cloves
clove	mass	7 lb	wool
clove	mass	8 lb	butter, cheese
ell, English	length	45 in	cloth
ell, Flemish	length	27 in	cloth
ell, French	length	54 in	cloth
firkin	volume	9 gal	ale, beer (UK)
firkin	mass	56 lb	butter
firkin	mass	64 lb	soap
fodder	mass	2400 lb	lead
goad	length	4½ ft	
hand	length	4 in	heights of horses
hank	length	840 yd	cotton yarns
hide	area	100 acres	land
keg	mass	100 lb	nails
last	volume	80 bu	grain, etc
last	mass	1700 lb	feathers, flax
last	mass	2400 lb	gunpowder
mite	mass	1/20 gr	moneyweight
nail	length	2¼ in	cloth
noggin	volume	¼ pt	liquids
piece	length	10 yd	muslin
piece	length	28 yd	calico
pocket	mass	182 lb	wool
pottle	volume	4 pt	liquids
seam	volume	8 bu	grain
seam	mass	120 lb	glass
skein	length	360 ft	cotton yarn
stone	mass	5 lb	glass
stone	mass	16 lb	cheese
stone	mass	32 lb	hemp
tod	mass	28 lb	wool
truss	mass	36 lb	straw
truss	mass	56 lb	old hay
truss	mass	60 lb	new hay
wey	mass	182 lb	wool
yard of land	area	30 acres	land

Some Conversions in the Imperial System

There are

2 pints in a quart
3 feet in a yard
4 quarts in a gallon
5½ yards in a rod, pole, or perch
6 feet in a fathom
8 gallons in a bushel
8 furlongs in a mile
9 square feet in a square yard
12 inches in a foot
14 pounds in a stone
16 ounces in a pound
22 yards in a chain
32°F for the freezing point of water
40 fluid ounces in a quart (imperial)
100 links in a chain
100 pounds in a hundredweight (short)
112 pounds in a hundredweight (long)
212°F for the boiling point of water
220 yards in a furlong
360 degrees in a revolution
640 acres in a square mile
1728 cubic inches in a cubic foot
1760 yards in a mile
2000 pounds in a short ton
2240 pounds in a long ton
4840 square yards in an acre
5280 feet in a mile
6080 feet in a nautical mile
7000 grains in a pound (avoirdupois)

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602 SI counterparts of units to be discontinued

Table 20 Units to be adopted during metric conversion

	Imperial and metric units that are to be phased out	SI units and those that are permitted for use with SI
Length	inch, foot, yard, mile	millimetre, centimetre, decimetre*, metre, kilometre
	micron	micrometre
	angstrom	nanometre
Area	square inch, square foot, square yard, acre, square mile	square centimetre, square decimetre*, square metre, hectare, square kilometre
Volume	cubic inch, cubic foot, cubic yard	cubic centimetre, cubic decimetre*, cubic metre
	fluid ounce, pint, quart, gallon, bushel	millilitre, litre kilolitre*
Mass	ounce, pound, ton	gram, kilogram, tonne
Temperature	degree Fahrenheit, degree centigrade	degree Celsius, kelvin
Speed	mile per hour	kilometre per hour, metre per second*
Frequency	cycle per second	hertz, kilohertz, etc.
Force	pound-force, kilogram-force, dyne, poundal	newton, kilonewton, etc.
Pressure	pound per square inch, kilogram-force per square centimetre, torr, millimetre of mercury, bar, millibar, atmosphere	pascal, kilopascal, etc.
Energy	foot pound-force, BTU, horsepower hour, kilowatt hour, therm, erg, calorie, foot poundal	joule, kilojoule, etc.
Luminous intensity	candle	candela
Illumination	foot candle	lux
Conductance	mho	siemens

*May not be common, but can be useful in teaching.

603 Changes to be implemented

The following is a list of items that are to undergo change as Canada adopts the metric system. These changes are those related to the style in which measured quantities are expressed. This is a brief summary and does not include all changes mentioned in this guide.

Some changes are of an optional nature, but others are mandatory. The reader should refer to the sections listed at the end of each statement to obtain a fuller understanding of the change indicated.

There will be changes such as the following:

a) *From* the imperial system and former metric systems *to* SI. 113-115, 410

b) *From* miscellaneous abbreviations for units *to* unique international symbols for units. 312, 615

c) *From* some non-uniform spellings *to* more uniform spellings, such as for metre and litre. 122, 130, 141

d) *From* degrees Fahrenheit and degrees centigrade *to* degrees Celsius. 114, 136

e) *From* optional pronunciation of "kilometre" hopefully *to* a more rational pronunciation where the accent is placed on the first syllable as is the case with all prefixed units. 123

f) *From* what has often been a separation of "cubic" units and "capacity" units of volume *to* a closer blend of all volume units. 160, 161, 231, 232

g) *From* a rather vague and ambiguous use of the term "weight" *to* a more distinctive use of the terms "mass" and "force of gravity" ("weight" may continue to be used, but hopefully only in cases where its meaning is clearly understood). 134, 240-244, 530-532, 614

h) *From* the confusing practice of stating the date for example, for April 7, 1975, as 4/7/75 or 7/4/75 *to* recommended numeric dating, such as 1975 04 07. 251

i) *From* times in the morning and afternoon being stated with a.m. and p.m. *to* the 24-hour clock. 252

j) *From* stating temperature intervals in C° *to* °C or K. 260, 261, 522

k) *From* the use of degrees, minutes, and seconds for expressing angles *to* the preferred use of the decimal degree, except possibly on maps. 271

l) *From* a haphazard use of quantity symbols *to* a more standardized use, where quantity symbols are preferably printed in sloping type. 320, 322, 616

m) *From* abbreviations for squared and cubed units *to* symbols that show the exponents ^{2} and ^{3}. 342h

n) *From* abbreviations for units *to* international symbols that are not pluralized or followed by a period. 342d, 342e

o) *From* an over-emphasis of common fractions *to* a more predominant use of decimal fractions. 343d

p) *From* the use of commas in large numerals *to* the use of spaces to separate digits into groups of three. 333, 343c

q) *From* the habit of starting some numerals with a decimal marker *to* the use of a zero to the left of the marker if there is no other digit there. 343e

r) *From* sometimes using a raised dot as a multiplier with numerals *to* only using the raised dot as a multiplier with symbols. 343i, 342 l

s) *From* the use of non-coherent units *to* a greater emphasis on coherent units. 413, 414

t) *From* the use of the terms "specific gravity" and "specific weight" *to* the term "relative density". 542

u) *From* the use of the kilogram-force *to* the use of the newton; *from* the Calorie *to* the kilojoule; and *from* the kilogram-force per square centimetre *to* the kilopascal—as examples of some of the changes required in adopting SI. 416, 432, 532, 552, 560-562

v) *From* stating frequency in cycles per second *to* stating it in hertz. 416

w) *From* the stating of atmospheric pressure in inches or millimetres of mercury *to* expressing it in kilopascals. 550, 551

x) *From* expressing gasoline consumption by a car in miles per gallon *to* stating it in litres per hundred kilometres. 573

y) *From* generally stating densities in grams per cubic centimetre *to* expressing them in kilograms per cubic metre or perhaps in grams per litre—this latter expression being reserved particularly for liquids and particulate matter, such as sand, salt, sugar, etc. 541

Rules of thumb for adults only
(Not to be used in the classroom)

The following rules are given reluctantly. They are intended only for those adults who must use them during a short transition period. The sooner these rules are not relied upon, the better. Try to *think metric*, not convert. Do not use these rules with students! Note: All these rules are approximate.

10% rule of thumb
1 m is 10% longer than 1 yd.
1 ℓ is 10% less than 1 qt.
1 kg is 10% more than 2 lb.
1 t is 10% more than 1 ton (short).

10-20-30 rule of thumb
1 m is 10% longer than 1 yd.
1 m^2 is 20% greater than 1 sq. yd.
1 m^3 is 30% greater than 1 cu.yd.

"30" rule of thumb
1 ft. is about 30 cm
1 fl. oz. is almost 30 ml
1 oz. (avdp) is almost 30 g

Miscellaneous
1 in. is about 25 mm or 2.5 cm
4 in. is about 10 cm
5 mi. is about 8 km

Air temperature rule
This rule applies only to temperatures between 0°F and 100°F.

To obtain the number of degrees Celsius (°C), subtract 30 from the number of degrees Fahrenheit (°F) and then divide by two. For example:

$$70°F = \frac{70-30}{2}\ °C \text{ (approx)}$$
$$= 20°C$$

70°F is actually just over 21°C

Oven rule
This rule applies only to oven temperatures between about 250°F and 450°F.

To obtain the Celsius temperature for setting the oven, halve the Fahrenheit temperature.

Gas consumption rule
If you know the number of miles per gallon that your car travels, divide this number into 280 to obtain the number of litres per hundred kilometres. See 573.

605 Conversion factors

The following conversion factors are given for the personal use of teachers only. These factors should not be used with students unless there is a justifiable reason for doing so. Those factors which are exact are in bold type.

Length	1 inch = **25.4** mm 1 foot = **30.48** cm 1 yard = **0.9144** m 1 mile = **1.609 344** km
Area	1 square inch = **6.4516** cm^2 1 square foot = **9.290 304** dm^2 1 square yard = 0.836 127 4 m^2 1 acre = 0.404 685 6 ha 1 square mile = 2.589 988 km^2
Volume	1 cubic inch = **16.387 064** cm^3 1 cubic foot = 28.316 85 dm^3 (or litres) 1 cubic yard = 0.764 555 m^3 1 fluid ounce = 28.413 062 cm^3 1 gallon = **4.546 090** dm^3 (or litres)
Mass	1 ounce (avoirdupois) = 28.349 523 g 1 pound (avoirdupois) = **0.453 592 37** kg 1 ton (short, 2000 lb) = **907.184 74** kg
Temperature	(**5**/**9**) × (number of degrees Fahrenheit − **32**) = number of degrees Celsius
Speed	1 mile per hour = **0.447 04** m/s = **1.609 344** km/h
Force	1 pound-force = 4.448 222 N 1 kilogram-force = **9.806 65** N
Pressure	1 pound-force per square inch (psi) = 6.894 757 kPa 1 inch of mercury (0°C) = 3.386 39 kPa 1 mm of mercury (0°C) = 133.322 Pa 1 standard atmosphere (atm) = **101.325** kPa
Energy, Work	1 British thermal unit (Btu) = 1055.06 J 1 foot pound force = 1.355 818 J 1 calorie (international) = **4.1868** J 1 kilowatt hour (kW·h) = **3.6** MJ
Power	1 horsepower (550 ft.lbf/s) = 745.6999 W 1 horsepower (electric) = **746** W

606 SI base units and their definitions

Table 21 SI base units

Quantity or attribute	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Definitions of the base units

The *metre* is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.

The *kilogram* is equal to the mass of the international prototype of the kilogram kept at the International Bureau of Weights and Measures.

The *second* is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.

The *ampere* is that current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 m apart in vacuum, would produce between these conductors a force equal to 0.2 μN/m of length.

The *kelvin*, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.

Note: The triple point of water has a temperature of 0.01°C, hence 0°C corresponds to 273.15 K.

The *mole* is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kg of carbon-12.

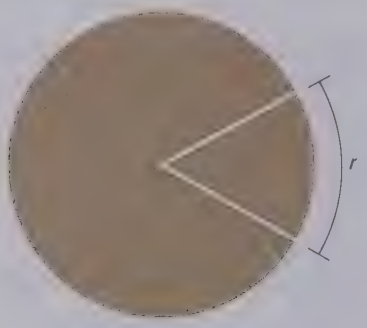
The *candela* is the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 m^2 of a black body (full radiator) at the temperature of freezing platinum under a pressure of 101.325 kPa.

607 SI supplementary units and their definitions

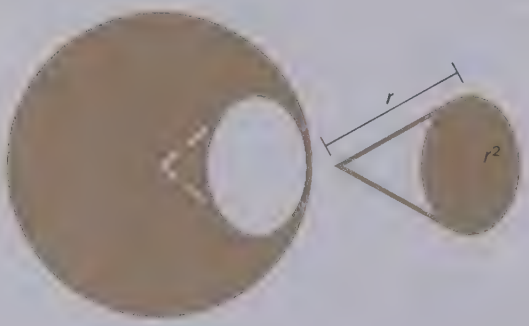
Table 22 SI supplementary units

Quantity or Attribute	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

The *radian* is the plane angle between two radii of a circle which cut off on the circumference an arc equal in length to the radius.



The *steradian* is the solid angle which, having its vertex at the centre of a sphere, cuts off an area of the surface of the sphere equal to that of a square with sides of length equal to the radius of the sphere.



608 SI derived units with special names

The following list of units is the complete set of derived units having special names–15 in all.

Table 23 SI derived units with special names

Quantity	Unit	Symbol	Definition
Frequency	hertz	Hz	$1/s$ or s^{-1}
Force	newton	N	$kg \cdot m/s^2$
Pressure, Stress	pascal	Pa	N/m^2
Energy, Work	joule	J	$N \cdot m$
Power	watt	W	J/s
Electric charge	coulomb	C	$A \cdot s$
Potential difference	volt	V	W/A or J/C
Electric resistance	ohm	Ω	$V/A \cdot$
Electric conductance	siemens	S	A/V
Electric capacitance	farad	F	C/V
Magnetic flux	weber	Wb	$V \cdot s$
Magnetic induction	tesla	T	Wb/m^2
Inductance	henry	H	Wb/A
Luminous flux	lumen	lm	$cd \cdot sr$
Illumination	lux	lx	lm/m^2

Note: The following two derived units with special names have recently been added to SI.

a) The becquerel (symbol Bq), the unit of activity of radioactive source, and is defined as one disintegration per second. ($1\ Bq = 1\ s^{-1}$)

b) The gray (symbol Gy), the unit of absorbed dose of ionizing radiation, and is defined as one joule per kilogram. ($1\ Gy = 1\ J/kg$)

The becquerel is named after Antoine Henri Becquerel (1852-1908) of France. The gray is named after Louis Harold Gray (1905-) of England.

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Definitions of derived units with special names

One *hertz* is the frequency of a periodic occurrence which has a period of 1 s. This unit was called the cycle per second. ($1\ Hz = 1\ s^{-1}$)

One *newton* is the force which, when applied to a mass of 1 kg, gives it an acceleration of 1 m/s^2. ($1\ N = 1\ kg \cdot m/s^2$)

One *pascal* is the pressure resulting from a force of 1 N acting uniformly over an area of 1 m^2. ($1\ Pa = 1\ N/m^2$)

One *joule* is the work done when the point of application of a force of 1 N is displaced through a distance of 1 m in the direction of the force. ($1\ J = 1\ N \cdot m$)

One *watt* is the power available when energy of 1 J is expended in 1 s. ($1\ W = 1\ J/s$)

One *coulomb* is the charge transported in 1 s by a current of 1 A. ($1\ C = 1\ A \cdot s$)

One *volt* is the difference in potential between two points of a conducting wire carrying a constant current of 1 A, when the power dissipated between these points is equal to 1 W. ($1\ V = 1\ W/A$)

One *farad* is the capacitance of a condenser having a charge of 1 C, across the plates of which the potential difference is 1 V. ($1\ F = 1\ C/V$)

One *ohm* is the resistance between two points of a conductor when a constant difference of potential of 1 V applied between these two points produces in this conductor a current of 1 A, the conductor not being the source of any electromotive force. ($1\ \Omega = 1\ V/A$)

One *siemens* is the conductance between two points of a conductor when a constant current of 1 A in the conductor produces a potential difference of 1 V between these two points and when the conductor itself is not the source of any electromotive force. ($1\ S = 1\ A/V = 1\ \Omega^{-1}$)

Note: The siemens was formerly called the mho or reciprocal ohm. (In SI, there is no mho.)

One *weber* is the magnetic flux which, linking a circuit of one turn, produces in it an electromotive force of 1 V as it is reduced to zero at a uniform rate in 1 s. ($1\ Wb = 1\ V \cdot s$)

One *tesla* is the magnetic induction that is equal to 1 Wb of magnetic flux per square metre. ($1\ T = 1\ Wb/m^2$)

One *henry* is the inductance of a closed circuit which gives rise to a magnetic flux of 1 Wb/A. ($1\ H = 1\ Wb/A$)

One *lumen* is the flux emitted in a cone of solid angle of 1 sr by a spherical point source of uniform luminous intensity of 1 cd. ($1\ lm = 1\ cd \cdot sr$)

One *lux* is the illumination (or illuminance) of 1 lm uniformly over an area of 1 m^2. ($1\ lx = 1\ lm/m^2$)

Units and the names of scientists

Table 24 SI units named after scientists

Unit	Scientist	Country of birth	Dates
ampere	Ampère, André-Marie	France	1775-1836
coulomb	Coulomb, Charles Augustin de	France	1736-1806
degree Celsius	Celsius, Anders	Sweden	1701-1744
farad	Faraday, Michael	England	1791-1867
henry	Henry, Joseph	United States	1797-1878
hertz	Hertz, Heinrich Rudolph	Germany	1857-1894
joule	Joule, James Prescott	England	1818-1889
kelvin	William Thomson, Lord Kelvin	England	1824-1907
newton	Newton, Sir Isaac	England	1642-1727
ohm	Ohm, Georg Simon	Germany	1787-1854
pascal	Pascal, Blaise	France	1623-1662
siemens	Siemens, Karl Wilhelm later Sir William	Germany (England)	1823-1883
tesla	Tesla, Nikola	Croatia (United States)	1856-1943
volt	Volta, Count Alessandro	Italy	1745-1827
watt	Watt, James	Scotland	1736-1819
weber	Weber, Wilhelm Eduard	Germany	1804-1891

611 Some SI derived units with compound names

Table 25 Derived units with compound names

Quantity or Attribute	Unit	Symbol
Area	square metre	m^2
Volume	cubic metre	m^3
Speed, Velocity	metre per second	m/s
Acceleration	metre per second squared	m/s^2
Angular velocity	radian per second	rad/s
Angular acceleration	radian per second squared	rad/s^2
Volume flow rate	cubic metre per second	m^3/s
Mass flow rate	kilogram per second	kg/s
Density (mass density)	kilogram per cubic metre	kg/m^3
Momentum	kilogram metre per second	kg·m/s
Viscosity: kinematic	square metre per second	m^2/s
Viscosity: dynamic	pascal second	Pa·s
Surface tension	newton per metre	N/m
Moment of force, Torque	newton metre	N·m
Moment of inertia	kilogram metre squared	$kg·m^2$
Second moment of area	metre to the fourth power	m^4
Angular momentum	kilogram metre squared per second	$kg·m^2/s$
Specific latent heat	joule per kilogram	J/kg
Heat capacity	joule per kelvin	J/K
Specific heat capacity	joule per kilogram kelvin	J/(kg·K)
Heat conductivity	watt per metre kelvin	W/(m·K)
Heat flux density	watt per square metre	W/m^2
Electric field strength	volt per metre	V/m
Magnetic field strength	ampere per metre	A/m
Molar mass	kilogram per mole	kg/mol
Molar volume	cubic metre per mole	m^3/mol
Molar internal energy	joule per mole	J/mol
Concentration	mole per cubic metre	mol/m^3
Molality	mole per kilogram	mol/kg
Radiant intensity	watt per steradian	W/sr
Luminance	candela per square metre	cd/m^2
Quantity of light	lumen second	lm·s
Light exposure	lux second	lx·s

Note: In the above table, the K may be replaced by °C.

612 Some non-SI units permitted for use with SI

Table 26 Non-SI units permitted universally with SI

Permitted unit and symbol	Value and application		
minute (min)	1 min	=60 s	time
hour (h)	1 h	=60 min	time
day (d)	1 d	=24 h	time
degree of arc (°)	180°	$=\pi$ rad	angle
minute of arc (′)	60′	=1°	angle
second of arc (″)	60″	=1′	angle
litre (ℓ)	1 ℓ	$=1\ dm^3$	volume
tonne (t)	1 t	=1000 kg=1 Mg	mass

Table 27 Non-SI units permitted in specialized fields

Permitted unit and symbol	Value and application		
hectare (ha)	1 ha	$=10\,000\ m^2$	area
astronomical unit (AU)*	1 AU	=149.6 Gm	length
parsec (pc)	1 pc	=30 857 Tm	length
electronvolt (eV)	1 eV	=0.160 aJ	energy
unified atomic mass unit (u)	1 u	$=1.66\times10^{-27}$ kg	mass

Table 28 Non-SI units permitted for a limited time

Permitted unit and symbol	Value and application		
nautical mile (n.mi.)*	1 n.mi.	=1852 m	length
knot (kn)*	1 kn	=0.51 m/s	speed
bar (bar)	1 bar	=100 kPa	pressure
standard atmosphere (atm)	1 atm	=101.325 kPa	pressure
kilowatt hour (kW·h)	1 kW·h	=3.6 MJ	energy

*These abbreviations are not international symbols.

613 Some metric units that should not be used with SI

Table 29 Metric units not to be used with SI

Obsolete unit and symbol	Value and application		
micron (μ)	1 μ	=1 μm	length
angstrom (Å)	1 Å	=0.1 nm	length
kilogram-force (kgf)	1 kgf	=9.8 N	force
dyne (dyn)	1 dyn	=10 μN	force
calorie (cal)	1 cal	=4.19 J	energy
erg (erg)	1 erg	=0.1 μJ	energy
stere (st)	1 st	$=1\ m^3$	volume
millimetre of mercury, torr	1 torr	$=\frac{101\,325}{760}$ Pa	pressure

Some others in this category are oersted, maxwell, gauss, poise, stokes, and metric carat.

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Variations in the "force of gravity"

Here, instead of using the word "weight", the expression "force of gravity" is used.

In 532 it is claimed that a man, having a *mass* of 80.0 kg, experiences a *force of gravity* of 784 N on the earth and only 128 N on the moon.

On earth the acceleration due to gravity is about 9.80 m/s^2 and on the moon it is about 1.60 m/s^2. Since force = mass times acceleration, the man experiences
a force of gravity on the earth equal to
$80.0\ kg \times 9.80\ m/s^2 = 784\ kg \cdot m/s^2 = 784\ N$
a force of gravity on the moon equal to
$80.0\ kg \times 1.60\ m/s^2 = 128\ kg \cdot m/s^2 = 128\ N$

On the earth, the man's mass is 80.0 kg; the force of gravity acting on him is 784 N.

On the moon, the man's mass is 80.0 kg; the force of gravity acting on him is 128 N.

Every kilogram mass on the surface of the world requires a force of about 9.80 N to lift it against the pull of gravity. The force of gravity can be thought of as 9.80 N/kg on each object at the surface of the earth.

In a similar way, the force of gravity is 1.60 N/kg on each object at the surface of the moon.

Using this concept, we can again calculate the force of gravity acting on the man. He experiences
a force of gravity on the earth equal to
$80.0\ kg \times 9.80\ N/kg = 784\ N$
a force of gravity on the moon equal to
$80.0\ kg \times 9.80\ N/kg = 128\ N$
as calculated above.

It is of interest to know that the force of gravity varies slightly over the surface of the earth. If the man's mass were 80.0 kg, he would experience the force of gravity as follows:
784 N at sea level at 45° latitude,
786 N at the North Pole,
782 N at the equator, and
781 N at the top of Mount Everest.

Mass remains constant while the force of gravity acting on the mass varies from place to place.

The "weight" of the man depends on what is meant by "weight". The general public would say that he weighs 80.0 kg–here, "weight" means *mass*. The physicist would say that he weighs about 784 N–here, "weight" would mean *force of gravity*.

It is therefore suggested that the word "weight" be used only in situations where its meaning is perfectly clear within the context in which the student is working.

List of units and their symbols

This list includes most of the units shown in this guide. Old-fashioned or imperial units are not included unless they are permitted for use with SI. The units are classified under various categories as follows:
S/indicates an SI unit, SI multiple or sub-multiple, or a prefix;
P/indicates a non-SI unit that is *permitted* for use with SI on a continuing basis, until further notice;
L/indicates a non-SI unit that is permitted for use with SI for a *limited* time, a unit that should not be tolerated for a longer period than is necessary;
O/indicates an *obsolete* metric unit that is not permitted for use with SI.

Table 30 Units and their symbols

Unit	Symbol	S	P	L	O	Quantity or prefix value
ampere	A	■				Electric current
ampere per metre	A/m	■				Magnetic field strength
angstrom	Å				■	Length
are	a				■	Area
astronomical unit	AU*		■			Length
atmosphere, standard	atm			■		Pressure
atomic mass unit	u		■			Mass
atto (prefix)	a	■				10^{-18}
attojoule	aJ	■				Energy
attometre	am	■				Length
bar	bar			■		Pressure
calorie	cal				■	Energy
Calorie (kilocalorie)	Cal				■	Energy
candela	cd	■				Luminous intensity
candela per square metre	cd/m^2	■				Luminance
centi (prefix)	c	■				10^{-2}
centilitre	cl		■			Volume
centimetre	cm	■				Length
coulomb	C	■				Electric charge
cubic centimetre	cm^3	■				Volume
cubic decimetre	dm^3	■				Volume
cubic metre	m^3	■				Volume
cubic metre per mole	m^3/mol	■				Molar volume
cubic metre per second	m^3/s	■				Volume flow rate
day	d		■			Time
deca (prefix)	da	■				10
decalitre	dal		■			Volume
decametre	dam	■				Length

Unit	Symbol	S	P	L	O	Quantity or prefix value
deci (prefix)	d	■				10^{-1}
decilitre	dl		■			Volume
decimetre	dm	■				Length
degree Celsius	°C		■			Temperature (common)
degree (of arc)	°		■			Angle
dyne	dyn				■	Force
electronvolt	eV		■			Energy
erg	erg				■	Energy
farad	F	■				Electric capacitance
femto (prefix)	f	■				10^{-15}
femtometre	fm	■				Length
gauss	Gs or G				■	Magnetic flux density
giga (prefix)	G	■				10^{9}
gigametre	Gm	■				Length
gigapascal	GPa	■				Pressure
gram	g	■				Mass
gram per cubic centimetre	g/cm^3	■				Density
gram per litre	g/ℓ		■			Density
gram per millilitre	g/ml		■			Density
hectare	ha		■			Area
hecto (prefix)	h	■				10^{2}
hectometre	hm	■				Length
henry	H	■				Inductance
hertz	Hz	■				Frequency
hour	h		■			Time
joule	J	■				Energy
joule per kelvin	J/K	■				Heat capacity
joule per kilogram	J/kg	■				Specific latent heat
joule per kilogram kelvin	J/(kg·K)	■				Specific heat capacity
joule per mole	J/mol	■				Molar internal energy
kelvin	K	■				Temperature
kilo (prefix)	k	■				10^{3}
kilogram	kg	■				Mass
kilogram-force	kgf				■	Force
kilogram metre per second	kg·m/s	■				Momentum
kilogram metre squared	kg·m^2	■				Moment of inertia
kilogram metre squared per second	kg·m^2/s	■				Angular momentum
kilogram per cubic metre	kg/m^3	■				Density
kilogram per litre	kg/ℓ		■			Density
kilogram per mole	kg/mol	■				Molar mass
kilogram per second	kg/s	■				Mass flow rate
kilohertz	kHz	■				Frequency
kilokelvin	kK	■				Temperature
kilojoule	kJ	■				Energy
kilolitre	kl		■			Volume
kilometre	km	■				Length
kilometre per hour	km/h		■			Speed
kilonewton	kN	■				Force

Unit	Symbol	S	P	L	O	Quantity or prefix value
kilopascal	kPa	■				Pressure
kilowatt	kW	■				Power
kilowatt hour	kW·h			■		Energy
knot	kn*			■		Speed
light year	ly*					Length (1 ly=9460.5 Tm)
litre	ℓ		■			Volume
lumen	lm	■				Luminous flux
lumen second	lm·s	■				Quantity of light
lux	lx	■				Illuminance
lux second	lx·s	■				Light exposure
maxwell	Mx				■	Magnetic flux
mega (prefix)	M	■				10^{6}
megagram	Mg	■				Mass
megahertz	MHz	■				Frequency
megajoule	MJ	■				Energy
megakelvin	MK	■				Temperature
megametre	Mm	■				Length
meganewton	MN	■				Force
megawatt	MW	■				Power
metre	m	■				Length
metre per second	m/s	■				Speed, velocity
metre per second squared	m/s^2	■				Acceleration
metre to the fourth power	m^4	■				Second moment of area
micro (prefix)	μ	■				10^{-6}
micrometre	μm	■				Length
micron	μ				■	Length
milli (prefix)	m	■				10^{-3}
milligram	mg	■				Mass
millilitre	ml		■			Volume
millimetre	mm	■				Length
millimetre of mercury	mm of Hg*				■	Pressure
millipascal	mPa	■				Pressure
millisecond	ms	■				Time
minute	min		■			Time
minute (of arc)	′		■			Angle
mole	mol	■				Amount of substance
mole per kilogram	mol/kg	■				Molality
mole per cubic metre	mol/m^3	■				Concentration
nano (prefix)	n	■				10^{-9}
nanometre	nm	■				Length
nautical mile	n.mi.*			■		Length
newton	N	■				Force
newton metre	N·m	■				Moment of force, torque
newton per metre	N/m	■				Surface tension
oersted	Oe				■	Magnetic field strength
ohm	Ω	■				Electric resistance
parsec	pc		■			Length
pascal	Pa	■				Pressure
pascal second	Pa·s	■				Dynamic viscosity
pico (prefix)	p	■				10^{-12}
picometre	pm	■				Length
poise	P				■	Dynamic viscosity

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Unit	Symbol	S	P	L	O	Quantity or prefix value
radian	rad	■				Plane angle
radian per second	rad/s	■				Angular velocity
radian per second squared	rad/s^2	■				Angular acceleration
revolution per second	s^{-1} (r/s)	■	■			Rotational speed (permitted symbol)
second	s	■				Time
second (of arc)	″		■			Angle
siemens	S	■				Electric conductance
square centimetre	cm^2	■				Area
square metre	m^2	■				Area
square metre per second	m^2/s	■				Kinematic viscosity
square kilometre	km^2	■				Area
standard atmosphere	atm			■		Pressure
steradian	sr	■				Solid angle
stere	st				■	Volume
stokes	St				■	Kinematic viscosity
tera (prefix)	T	■				10^{12}
terametre	Tm	■				Length
tesla	T	■				Magnetic flux density
tonne (metric ton)	t		■			Mass
unit of atomic mass	u		■			Mass
volt	V	■				Electric potential
volt per metre	V/m	■				Electric field strength
watt	W	■				Power
watt per metre kelvin	W/(m·K)	■				Heat conductivity
watt per square metre	W/m^2	■				Heat flux density
watt per steradian	W/sr	■				Radiant intensity
weber	Wb	■				Magnetic flux
year (annum)	a		■			Time

*These are abbreviations, not international symbols

Quantities and their sloping symbols

Sloping symbols are used to represent physical quantities such as length, mass, and time. These symbols are not part of SI and are to be used on an optional basis. There is a trend toward more uniform acceptance of quantity symbols. In time, conformity toward the adoption of an international standard for sloping symbols may be recommended. The following is a partial list of sloping symbols selected from Column 1, Table 10 (pages 16-23) of the *Metric Practice Guide*-CAN-3-001-02-73. Greek symbols have been omitted.

Table 31 Quantities and their sloping symbols

Quantity	Sloping symbol
Acceleration	*a, g*
Area	*A*
Breadth	*b*
Capacitance (electric)	*C*
Charge	*Q*
Conductance (electric)	*G*
Current (electric)	*I*
Density	**D*
Diameter	*d*
Distance	**d*
Energy, Work	*E, W*
Flow (volume rate)	*q*
Force	*F*
Force of gravity	*G*
Frequency	*f*
Height	*h*
Length	*l*
Mass	*m*
Moment of force	*M*
Momentum	*p*
Period (time of one cycle)	*T*
Potential (electric)	*V*
Power	*P*
Pressure	*p*
Quantity of heat	*Q*
Radius	*r*
Relative density	*d*
Resistance (electric)	*R*
Rotational frequency	*n*
Specific heat capacity	*c*
Specific latent heat	*l*
Speed, velocity	*v, u, c*
Temperature (common)	*t*
Temperature (thermodynamic)	*T*
Thickness	*d*
Time	*t*
Torque	*T*
Velocity	*v, u, c*
Volume	*V*
Width	*w*

*Not mentioned in the *Metric Practice Guide*, but recommended here for possible use in schools.

The following chart includes many, but by no means all, of the symbols which represent SI units or non-SI units that are permitted for use with SI. The names of the units are listed in 615.

Table 32 SI in a nutshell

These are used to form all SI derived units.	**Base units** (7 of these)						
	m	kg	s	A	K	mol	cd
	Supplementary units (2 of these)						
	rad	sr					
These units are coherent SI derived units.	**Derived units** a) with special names (15 of these)*						
	Hz	N	Pa	J	W	C	V
	Ω	S	F	Wb	T	H	
	lm	lx					
	b) with compound names (partial list)						
	m^2	m^3	m/s	m/s^2	rad/s	rad/s^2	
	$kg \cdot m^2$	$kg \cdot m^2/s$	kg/mol	m^3/mol	kg/m^3	$kg \cdot m/s$	
	mol/m^3	mol/kg	cd/m^2	m^2/s	m^3/s	kg/s	
	$N \cdot m$	$Pa \cdot s$	N/m	J/K	J/kg	W/m^2	
	$J/(kg \cdot K)$	V/m	A/m	J/mol	W/sr		
	$lm \cdot s$	$lx \cdot s$					
These are used to form multiples and sub-multiples.	**Prefixes** (14 of these)**						
	T	G	M	k	h	da	
	d	c	m	μ	n	p	
	f	a					
These are permitted indefinitely.	**Permitted non-SI units** (partial list)						
	min	h	d	°	′	″	
	ℓ	t	°C				
	ha	AU†	pc	eV	u		
These are permitted for a while.	**Permitted temporarily** (partial list)						
	n.mi.†	kn†	kW·h	mbar	atm		
These are not to be used in SI.	**Obsolete metric units** (partial list)						
	μ	kgf	dyn	cal	erg	st	torr
	Oe	Gs	Mx	P	St	Å	

*Two more have been recently added—the becquerel (Bq) and the gray (Gy). See 608.

**Two more prefixes have been recently added—exa (E) and peta (P). See 421.

†These are not international symbols.

Part C

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C11367